SURVEY REPORT

(APPENDICES)

SAN ANTONIO RIVER WATERSHED

TEXAS

PROGRAM FOR RUNOFF AND WATERFLOW RETARDATION
AND SOIL EROSION PREVENTION

U.S. DEPARTMENT OF AGRICULTURE
NOVEMBER, 1952

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APPENDICES

SAN ANTONIO RIVER WATERSHED, TEXAS

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APPENDIX I

PHYSICAL FACTORS

DESCRIPTION OF THE AREA

The San Antonio River Watershed, which has a total area of 4,186 square miles, lies entirely within the State of Texas. The river is the largest tributary of the Guadalupe River.

The San Antonio River rises at San Antonio Springs in the city of San Antonio, although the Medina River, its major tributary, heads in northwestern Bandera County 75 miles to the northwest. The river flows in a southeasterly direction to its junction with the Guadalupe River about 10 miles from San Antonio Bay on the Gulf of Mexico. The San Antonio River Watershed has an overall length of approximately 195 miles and a maximum width of about 50 miles. It is bordered on the east and north by the Guadalupe River Watershed and on the west and south by the Nueces and Mission River Watersheds.

The principal tributaries of the San Antonio River from the headwaters downstream are Olmos and Salado Creeks, the Medina River and Cibolo, Ecleto, Escondido and Manahuilla Creeks.

PROBLEM AREAS IN SOIL CONSERVATION

The San Antonio River Watershed is composed of parts of 5 problem areas in soil conservation. These problem areas are distinguished by uniform physical and economic characteristics and are used as units to facilitate hydrologic and economic investigation, figure 1. Each problem area in soil conservation is an association of soil, crop adaptation, topography, cover and land utilization and is characterized by essentially uniform rates of runoff, sedimentation and deterioration of soil resources. A brief description of each problem area in soil conservation is given in the following pages.

Edwards Plateau: The Edwards Plateau occupies about 28 percent, table 1, of the San Antonio River Watershed and is located in the extreme headwaters, figure 1. The area is underlain by limestone and is an area of rugged hills and narrow valleys deeply dissected by streams. The dividing line of the Edwards Plateau area and the Rio Grande Plain is sharply defined by the steep hills and limestone bluffs that mark the Balcones Escarpment. General land elevations range from about 2,500 feet above sea level in northwestern Bandera County to approximately 1,000 feet along the escarpment just above San Antonio. Topography is usually unsuited to cultivation and soils are fine textured, shallow to very shallow and stony. Present plant cover is brushy grassland or a sparse and uneven grass cover with various amounts of live oak, cedar, mesquite trees and brush.

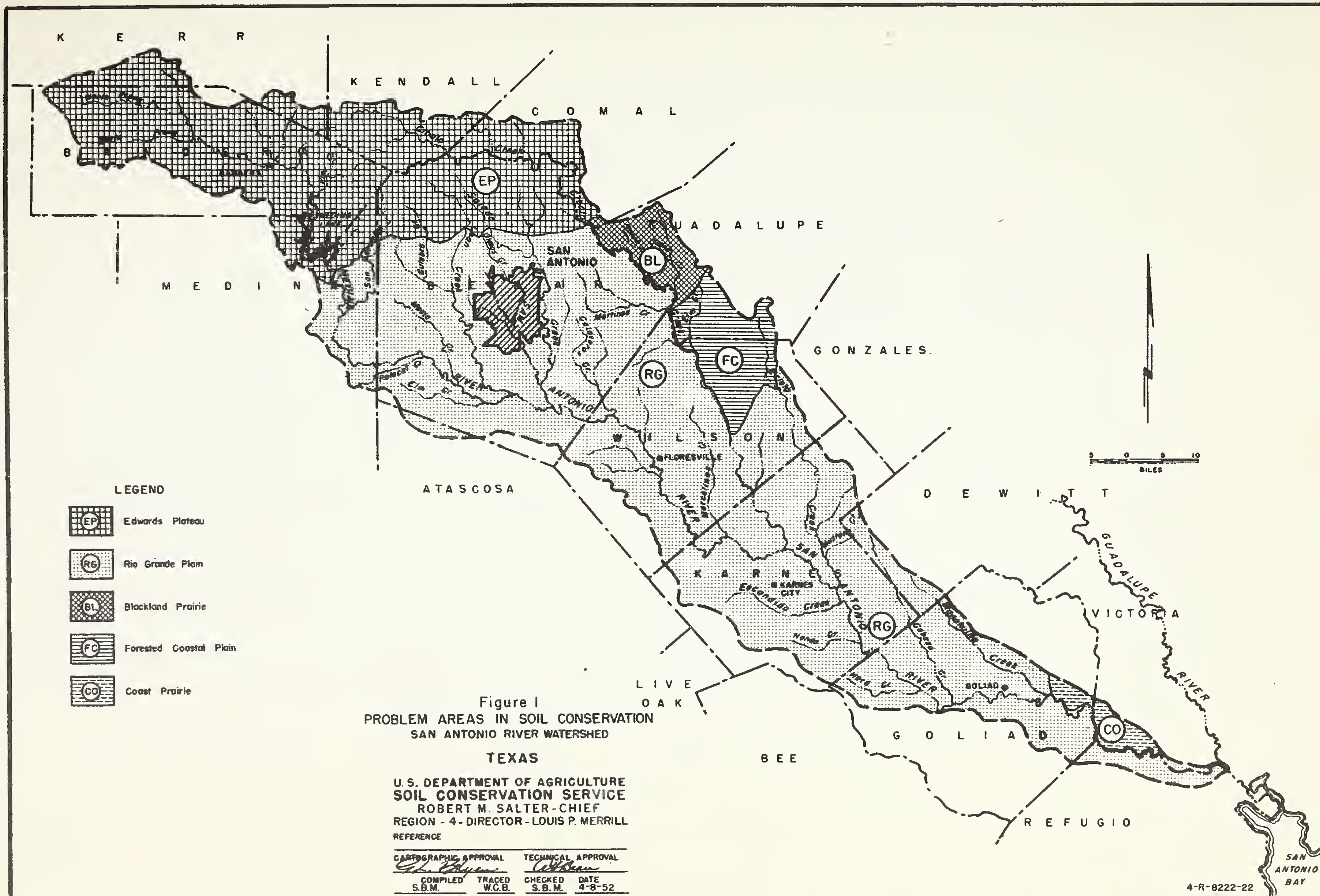

Figure I
PROBLEM AREAS IN SOIL CONSERVATION
SAN ANTONIO RIVER WATERSHED

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Table 1. Area of Problem Areas in Soil Conservation, by Creek Watersheds

San Antonio River Watershed, Texas

Creek Watershed	Problem Area in Soil Conservation					
	Coast Prairie	Rio Grande Plain	Forested Coastal Plain	Blackland Prairie	Edwards Plateau	Total
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Upper San Antonio	-	582,316	-	-	55,124	637,440
Lower San Antonio	18,110	455,490	-	-	-	473,600
Upper Medina	-	-	-	-	405,120	405,120
Lower Medina	-	327,445	-	-	122,475	449,920
Upper Cibolo	-	9,262	-	1,952	169,266	180,480
Lower Cibolo	-	261,685	60,777	51,938	-	374,400
Ecleto Creek	-	127,383	19,858	10,839	-	158,080
Total	18,110	1,763,581	80,635	64,729	751,985	2,679,040
Percent of Total	0.7	65.8	3.0	2.4	28.1	100.0

About 92 percent of the area, table 2, is grassland pastured by sheep, goats and cattle. Land used for crop production occupies about 6 percent of the area and is usually divided between the narrow valleys along major drainages and the smooth divides.

Rio Grande Plain: This problem area in soil conservation consists of a rolling plain with a general regional slope to the southeast. It occupies approximately 66 percent of the watershed, extending from just north of San Antonio to the mouth of the river. Most of the area lies at elevations between 200 and 700 feet above mean sea level although extreme elevations range from about 40 feet at the mouth of the San Antonio River to about 800 feet at the foot of the Balcones Escarpment.

Upland soils in central Bexar and western Karnes counties are primarily deep, dark colored, fine textured and slowly permeable with marl, clay or chalky marl parent materials. Deep, medium textured, slowly permeable sandy soils with marl parent materials occur in southern Bexar and most of Wilson counties. An exception to this is a strip of loose sandy soils which cuts across the area in northern Wilson and south-central Bexar counties. East from Karnes City and north from Goliad the uplands are a mixture of deep, fine textured and slowly permeable; deep, medium textured and slowly permeable; and deep, medium textured and permeable soils. The parent materials are predominately marls, clays and sandy clays. South from Goliad, in the rolling to flat area reaching to the mouth of the San Antonio River, the soils are predominately medium textured and slowly permeable.

Alluvial soils are found in both terrace and bottom positions. Most of the terrace soils are deep, fine textured and permeable dark colored loams while bottomland soils are usually deep, fine textured and slowly permeable.

Plant cover for the Rio Grande Plain area can be broken down into 3 distinct plant type associations, figure 2. They are the Mixed Prairie type in west-central Bexar and northeastern Medina counties; the Post Oak Savanna type which occupies narrow bands across the watershed in Goliad, Wilson and southwestern Bexar counties; and the Coast Prairie type in the remainder of the area.

About 65 percent of the Rio Grande Plain is grassland which is used primarily for grazing of beef cattle. Approximately 30 percent of this area is cropland and a small amount is in irrigated truck crops, but the majority is used for general crops. About 5 percent of the area is in non-farm and miscellaneous use.

Blackland Prairie: The Blackland Prairie area is located principally in northwestern Guadalupe County and occupies about 2.4 percent of the watershed. Surface topography is generally rolling with some smoothly undulating and flat areas. Sheet erosion is active and is generally classed as severe to critical in nature.

Soils of this area were formed from marl, chalk and calcareous clays and are usually dark colored and of heavy clay texture. Both

Table 2. Percentage of Various Land Uses by Problem Areas in Soil Conservation

San Antonio River Watershed, Texas

Problem Areas in Soil Conservation	Non-Farm Land	Cropland	Grassland	Woodland Pasture	Miscel-laneous Land	Total
	(percent)	(percent)	(percent)	(percent)	(percent)	(percent)
Coast Prairie	1.25	34.50	56.18	7.89	0.18	100.0
Rio Grande Plain	4.55	31.19	63.66	0	0.60	100.0
Forested Coastal Plain	1.82	18.41	22.34	56.86	0.57	100.0
Blackland Prairie	1.38	71.23	24.77	2.42	0.20	100.0
Edwards Plateau	1.49	5.93	90.67	1.79	0.12	100.0
Percent of Total for Watershed	3.51	24.70	69.01	2.33	0.45	100.0

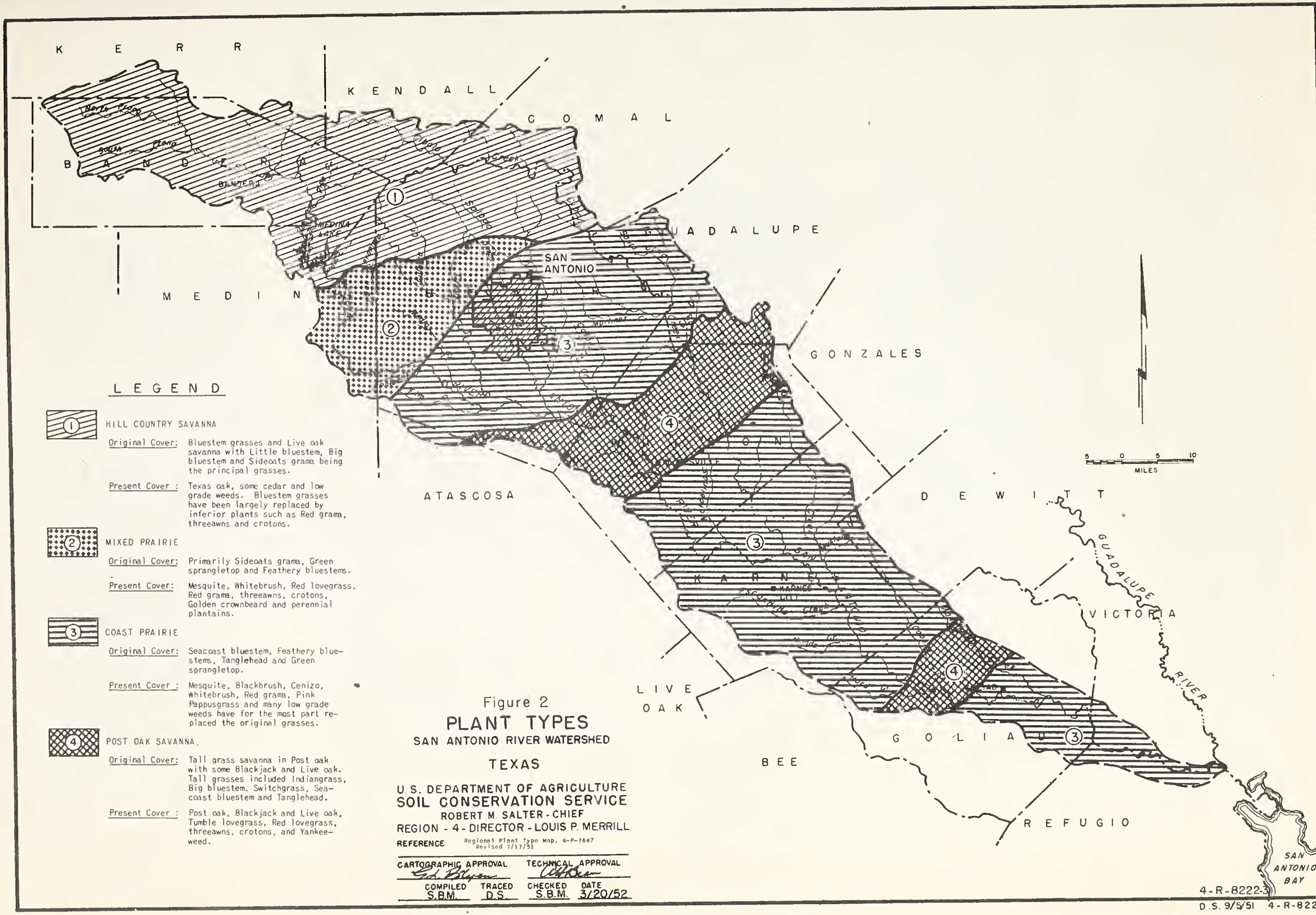

Figure 2
PLANT TYPES
SAN ANTONIO RIVER WATERSHED
TEXAS

surface soils and subsoils are granular in structure when dry and deep cracking is a common characteristic during prolonged dry spells. The soils swell on wetting and a high percentage of the rainfall runs off as surface flow. Plant cover was originally bluestem grasses with a scattered growth of mesquite trees and is now largely mesquite and other brushy growth with few desirable grasses. Ranges are generally in poor conditions.

This is the most intensively cultivated area in the San Antonio River Watershed with about 71 percent in cropland, 27 percent in pasture and the remainder in non-farm and miscellaneous uses.

Forested Coastal Plain: This area of deep, medium textured and slowly permeable soils and deep, coarse textured and freely permeable soils is located in eastern Wilson County from about Cibolo Creek east and covers about 3 percent of the San Antonio River Watershed. Topography is undulating to rolling with a savanna type plant cover of post oak, blackjack oak and live oak trees with various native grasses and weeds.

Erosion damage varies widely in accordance with the erodibility of the land and with past land use. In the major portion of the area the open porous soils absorb rainfall rapidly and there is little surface runoff with limited possibility for soil removal. The remainder of the area consists of sandy soils with slowly permeable subsoils. This condition is conducive to runoff and soil loss. Wind erosion is a hazard on the cultivated deep sandy soils.

Approximately 18 percent of this area is usually planted in peanuts, watermelons, corn, grain sorghums, cotton or other crops. About 80 percent is in pasture use and the remaining 2 percent is in miscellaneous and non-farm uses.

Coast Prairie: This problem area in soil conservation occupies approximately that portion of Victoria County drained by the San Antonio River or about 0.7 percent of the total watershed area. The topography is smooth to flat and elevations range from 40 to 100 feet above mean sea level. Soils are black to dark-gray in color, with dark-gray heavy clay subsoils over slightly calcareous clay parent materials. Surface and internal drainage is usually slow. Native vegetation consists chiefly of a thick cover of coarse prairie grasses. About 64 percent of this area is in grassland, 34 percent in cropland and 3 percent in miscellaneous uses.

GEOLOGY AND PHYSIOGRAPHY

The Gulf Coastal Plain and the Great Plains physiographic provinces contain the San Antonio River Watershed. Within the San Antonio River Watershed the division between the Great Plains and the Gulf Coastal Plain is a prominent southeast facing escarpment, produced by faulting, known as the Balcones Escarpment. It enters the watershed in northeast Medina County and continues in a direction approximately 60 degrees

east of north through Bexar County and southwestern Comal County. The locations and boundaries of the physiographic sections and outcrops of the principal geologic formations are shown in figure 3. Geologic formations ranging in age from Cretaceous to Recent are represented in the watershed. Descriptions of the various sections follow and table 3 describes the geologic formations included within the sections.

Great Plains Province

Edwards Plateau Section: This region is a sub-maturely dissected plateau, consisting of rolling prairie uplands, steep valley walls and mesa slopes, with local relief ranging from 400 to 800 feet. The age of all formations in the Edwards Plateau section of the watershed is Lower Cretaceous. The level to undulating uplands are underlain by the Washita and Fredericksburg groups; the former consisting of the hard and close grained Georgetown limestone, the Grayson shale (formerly Del Rio clay - the "big mud" of well drillers) and the uniformly dense and hard Buda limestone. Formations of the Fredericksburg group are the Edwards limestone, a cavernous and flinty stratum, the Comanche Peak limestone and the Walnut clay. In the vicinity of the streams which have sharply dissected the plateau border, the Edwards limestone forms prominent vertical bluffs and steep, rugged valleys.

The Trinity formation, which is represented almost entirely by the Glen Rose limestone, includes alternating hard and soft layers of from one to a few feet in thickness, which weather to a succession of small benches, giving the hillsides a characteristic terraced appearance.

Balcones Escarpment: A prominent feature of the watershed, already referred to, is the Balcones Escarpment which passes through the area in a southwest-northeast direction. To the northwest of the escarpment the country is high and hilly; to the southeast the land is hilly in places, but on the average is much lower in elevation and includes a larger amount of level land and flood plain. The escarpment indicates the location of the large faults and dips of the Balcones fault zone. The escarpment becomes less abrupt from west to east as the Edwards Plateau rises more gradually from the lowlands.

Gulf Coastal Plain Province

Black Prairie: This section includes all of the Upper Cretaceous formations which occur in the watershed. It is characterized by long gentle slopes, dark clay soils of high fertility, well developed drainage and low relief. The rock formations include a series of limestones, marls, clays and chalks of the Eagle Ford, Austin, Taylor and Navarro groups. The beds of these formations have low southeasterly dips and the western edge of the more resistant strata form low westward facing escarpments. The arrangement and approximate location of these formations are shown in figure 4.

South Texas Coastal Plain: Immediately southeast of San Antonio the San Antonio River enters the area of outcrop of Tertiary sands and

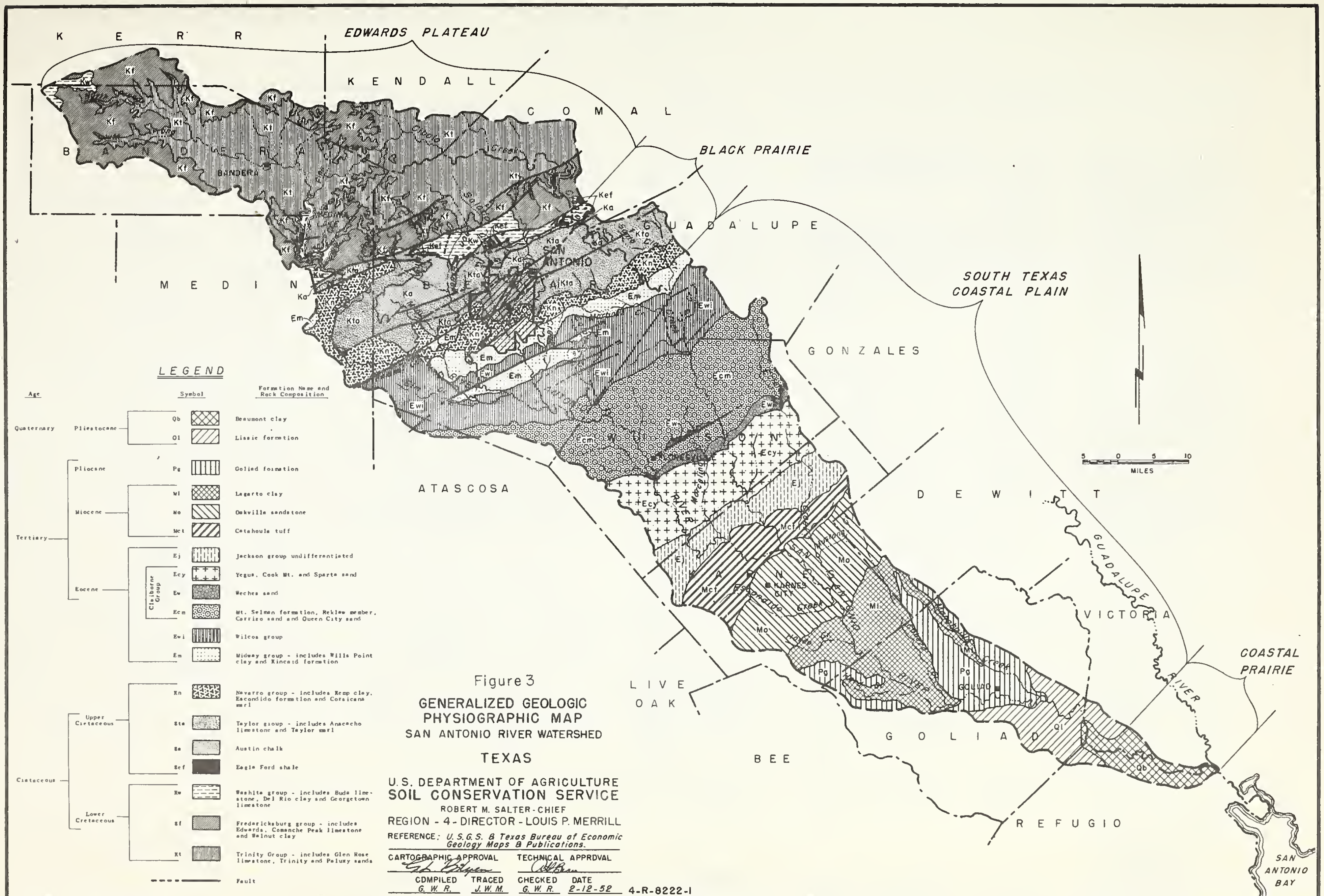

Figure 3

GENERALIZED GEOLOGIC PHYSIOGRAPHIC MAP
SAN ANTONIO RIVER WATERSHED

TEXAS

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SOIL CONSERVATION SERVICE
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REGION - 4 - DIRECTOR - LOUIS P. MERRILL
REFERENCE: U.S.G.S. & Texas Bureau of Economic Geology Maps & Publications.

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COMPILED G. W. R.	TRACED J. W. M.	CHECKED G. W. R.	DATE 2-12-52

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Table 3. Geologic Formations

San Antonio River Watershed, Texas

System	Series and Group	Formation	Thickness (feet)	Character of Rocks	Topography	Dominant Soil Characteristics	Rate of Influent Seepage	Ground Water Supply
Quaternary	Recent	Alluvium	0-60	Sand, gravel, silt and clay	Terraces and stream flood plains	Deep, light brown to black, calcareous, granular, clays, silty clays and sandy clays	Variable	Moderate amounts of good quality at shallow depths
	Pleistocene	Beaumont	300-900	Blue calcareous clay with lenses of sand and sandy clay	Flat to very gently sloping plain	Heavy, black calcareous clay	Very slow to moderate	Sands in this formation yield small quantities of fair quality
		Lissie	400-800	Gravels, sands and clays usually cemented into a limy conglomerate	Smooth, gently sloping plain	Gray to dark gray sandy to gravelly loams	Moderate	Large quantities of good quality
Tertiary	Pliocene	Goliad	200-400	Sands, clays, marls, caliche, gravels and indurated sandstones	Eroded ridges, valleys and cuestas	Black to dark brown, friable calcareous sandy clay loams	Moderate to rapid	Large amounts of good quality
	Miocene	Lagarto	350-650	Marly clays, sands and sandstones	Almost flat to gently sloping plain	Deep, black heavy clays	Moderate	Moderate amounts of fair quality from sand lenses
		Oakville	200-500	Gray, calcareous sandstone interbedded with lenses of clay and conglomerate	Broad rolling ridges with some escarpments	Sandy loams with sandy clay subsoils	Moderate to rapid	Large quantities of good quality
		Catahoula	600-800	Tuffaceous sandstone, argillaceous clay and volcanic tuff	Rolling, moderately dissected prairie with some escarpments	Clay loams to sandy loams	Moderate to rapid	Moderate amounts of fair to poor quality
	Eocene: Jackson Group	Fayette	400-800	Clays, sandy clays and gravels	Low hills and westward facing escarpments	Gray to brown silt loams and sandy loams	Slow to moderate	Small to moderate amounts of fair quality
	Eocene: Claiborne Group	Yegua	500-600	Clays, lignitic clay, sandy clays and sands	Gently rolling to rather level prairie	Dark, fertile clays and clay loams	Slow to moderate	Small to moderate amounts of fair quality
		Cook Mt. and Sparta	400-600	Soft clays and unconsolidated fine grained sands	Gently rolling, featureless prairie	Clays, sandy clays and sandy loams	Moderate	Small to moderate amounts of fair quality
		Weches	50-150	Glauconitic sands, clays and marls	Rolling, open prairie with hilly belts	Deep, reddish, sandy loams and clay loams	Moderate to rapid	Large amounts of good quality
		Mt. Selman	600-700	Brown and yellow sandstones interbedded with lignite and clay	Rolling to hilly dissected prairie	Gray to yellow sands with sandy clay subsoils	Moderate to rapid	Large amounts of good quality
		Reklaw	200-400	Glauconitic clays and some glauconitic sands	Gently rolling mature prairie	Deep red clays and sandy clays	Moderate	Moderate quantities of good quality
		Carrizo	200-400	Coarse-crystalline crossbedded sandstone	Ridges with moderate relief	Dark gray to yellow coarse sands to sandy loams	Rapid	Large quantities of good quality
	Eocene: Wilcox Group	Sabinetown, Rockdale and Seguin	200-600	Lignitic sands and clays	Moderately to steeply rolling hills	Fine sands and sandy loams underlain by sandy clays	Moderate to rapid	Moderate amounts of poor quality
	Eocene: Midway Group	Wills Point Kincaid	400-600	Compact clays to sandy and gypsiferous clays and some limestone	Gently undulating to rolling steep ridges in places	Calcareous clays and sandy clays	Slow	Small amounts of poor quality
Cretaceous	Upper Cretaceous	Navarro Group	400-500	Calcareous marls, glauconitic clays, interbedded sandstones and limestones	Moderately undulating to rolling plain	Clays, clay loams and sandy clays	Slow to moderate	Is not known to yield water to wells
		Taylor Group	400-600	Calcareous clays, marls and hard limestone	Gently rolling plains with wide valleys	Dark, heavy clays	Slow	Is not known to yield water to wells
		Austin	130 ±	Massive chalky limestone	Rounded hills with some prominent escarpments	Dark, heavy clays	Slow to Moderate	Small amounts of fair to poor quality
		Eagle Ford	25-40	Blue to yellow laminated shale	Gently rolling and subdued	Dark, heavy clays	Very slow	Does not yield water to wells
	Lower Cretaceous	Washita Group	160 ±	Cavernous limestone, laminated clay and marly limestones with interbedded shales	Gently to moderately sloping with some escarpments	Light brown, calcareous, friable, clays and clay loams	Slow	Georgetown limestone member yields small amounts of fair quality; otherwise does not yield water
		Fredericksburg Group	560 ±	Hard, flinty limestone, white marly limestone and marly laminated clays	Steep rugged plateau with high relief	Light brown, calcareous, friable, clays and clay loams	Moderate to rapid	Walnut clay and Commanche Peak limestone members do not yield water. Edwards limestone member yields large quantities of good quality
		Trinity Group	1000-1500	Largely cavernous limestone; some sands, sandstone and conglomerate	Steep to moderately sloping hills with high relief	Light brown, calcareous, friable, clays and clay loams	Slow to moderate	Glen Rose limestone yields small to moderate amounts of fair quality

UNITED STATES
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SOIL CONSERVATION SERVICE
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WESTERN GULF REGION
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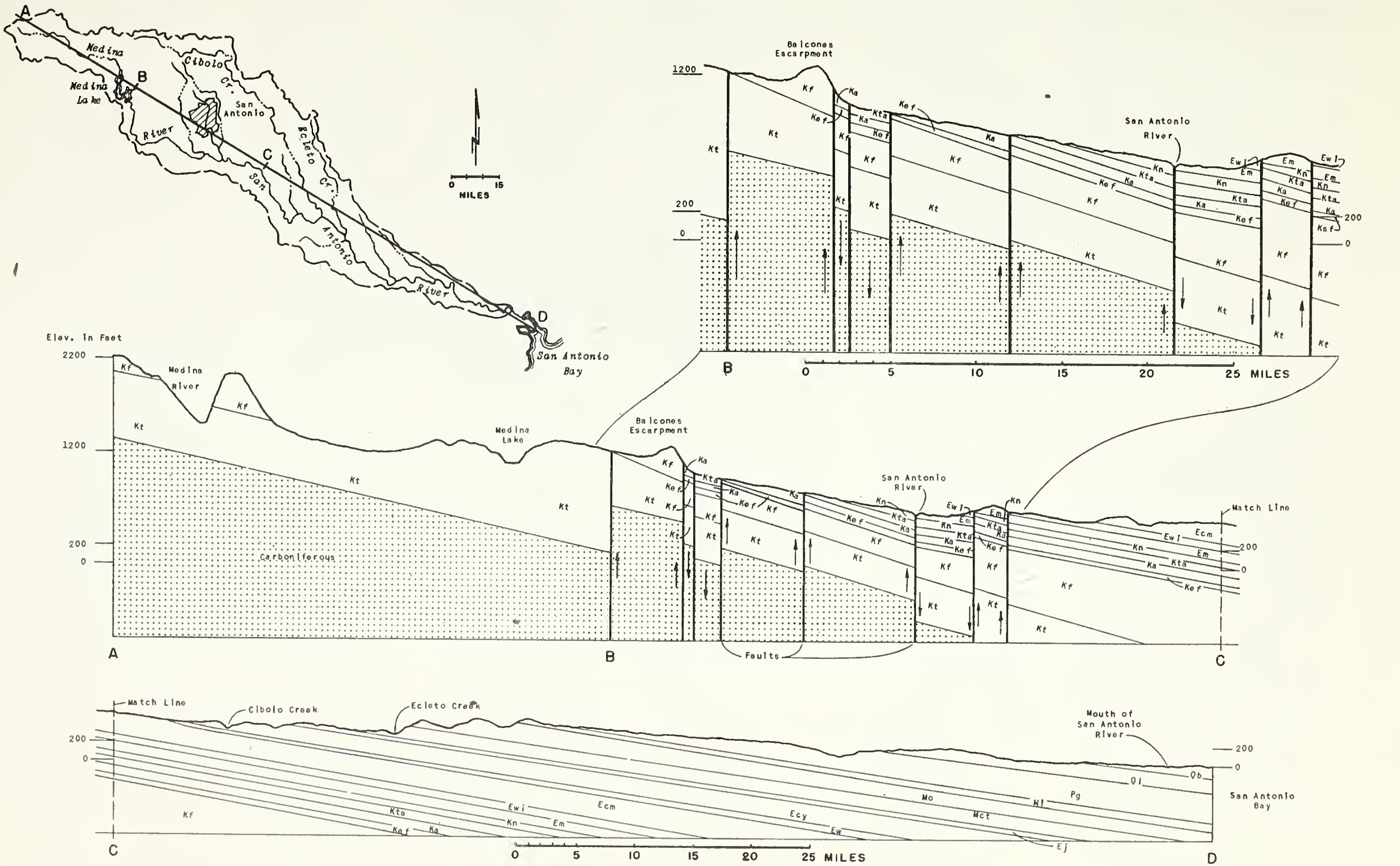

Figure 4
LONGITUDINAL GEOLOGIC CROSS SECTION
SAN ANTONIO RIVER WATERSHED
TEXAS

Refer to Legend on Generalized
Geologic-Physiographic Map,
Drawing Number 4-R-8222-1.

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sandy clays. These include, in descending order, the Midway, Wilcox, Claiborne and Jackson groups of Eocene age, the Catahoula, Oakville and Lagarto formations of Miocene age, the Goliad formation of Pliocene age, and the Lissie formation of Pleistocene age. This is the South Texas Coastal Plain and corresponds to the Rio Grande Plain and Forested Coastal Plain problem areas in soil conservation. The surface consists principally of alternating bands of clays and sands. Outcrops of lignite, glauconite, volcanic ash and iron oxide occur throughout the Eocene and Miocene formations. In general the area is one of subdued relief, wide shallow valleys and gentle slopes.

Coastal Prairie: A narrow belt of low flat coastal prairie is drained by the San Antonio River below Goliad County. The geologic formation represented in the area is the Beaumont clay of Pleistocene age. Throughout its extent it is more or less a unit of plastic, poorly bedded clay interbedded with lentils of sand. The valleys of this section are broad and shallow and the uplands are flat and generally featureless.

CLIMATIC FACTORS

Climate within the San Antonio River Watershed is continental in type, characterized by rapid changes in temperature and with marked diurnal and annual temperature extremes. A major portion of the watershed is in the subhumid climatic zone but the eastern portion borders on humid climatic conditions.

Average annual rainfall ranges from about 26 inches in the Edwards Plateau to 35 inches in the lower reaches of the watershed in Victoria County. Rainfall is fairly well distributed throughout the calendar year with the highest monthly precipitation occurring during the period from April through September. Rainfall in any portion of the watershed is erratic, and as a result extended droughts may occur. Additional information on rainfall is given in Appendix III.

Average annual temperatures range from about 65° F in the headwaters to 70° F in the lower stream reaches of the watershed. The length of the frost-free growing season is about 220 days in the Edwards Plateau. The watershed below the Balcones Escarpment shows little variation in length of growing season; 282 days at San Antonio and 283 days at Victoria.

Winters are usually short and mild but short light freezes of sufficient intensity to damage vegetable crops may occur throughout the watershed several times each winter. Snowfall is of rather rare occurrence, especially from San Antonio south, and the snow usually melts almost immediately.

Summers are long and hot with high day and moderate night temperatures.

CREEK WATERSHEDS

For convenience in hydrologic evaluations the watershed was divided into 7 creek watersheds, figure 5. These creek watersheds consist of portions of a major tributary river or may include many short tributary creeks. In general the drainage area between control points (reservoirs, gages, changes in upland characteristics, junction points of large tributaries etc.) is considered as a unit.

The area of problem areas in soil conservation included within each creek watershed is shown in table 1. Damages, costs and benefits are presented in later appendices by creek watersheds.

LAND USE

The percent of various land uses are shown by problem areas in soil conservation in table 2 and by creek watersheds in table 4. Data were obtained from the Conservation Jobs Ahead Study 1/ completed in 1945 and the Conservation Needs and Time Table Study 1/ completed in 1949. Census reports were used as a check for these data.

PRESENT PHYSICAL CONDITIONS

Soil, Slope and Erosion Conditions

Conservation survey data were used in the determination of physical conditions within each problem area in soil conservation and in sample watersheds. Approximately 1,500,000 acres have been mapped within or immediately adjoining the watershed and the data were tabulated as follows:

Problem Area in Soil Conservation	Acres Tabulated
Edwards Plateau	198,638
Rio Grande Plain	1,052,906
Blackland Prairie	139,270
Forested Coastal Plain	92,003
Coast Prairie	5,768
Total Acreage Tabulated	1,488,585

Soil units with similar characteristics were grouped in this tabulation and the percentages of total acreage within each problem area in soil conservation are shown in table 5. The various soil group names are self-explanatory.

1/ Soil Conservation Service, Region 4, Unpublished.

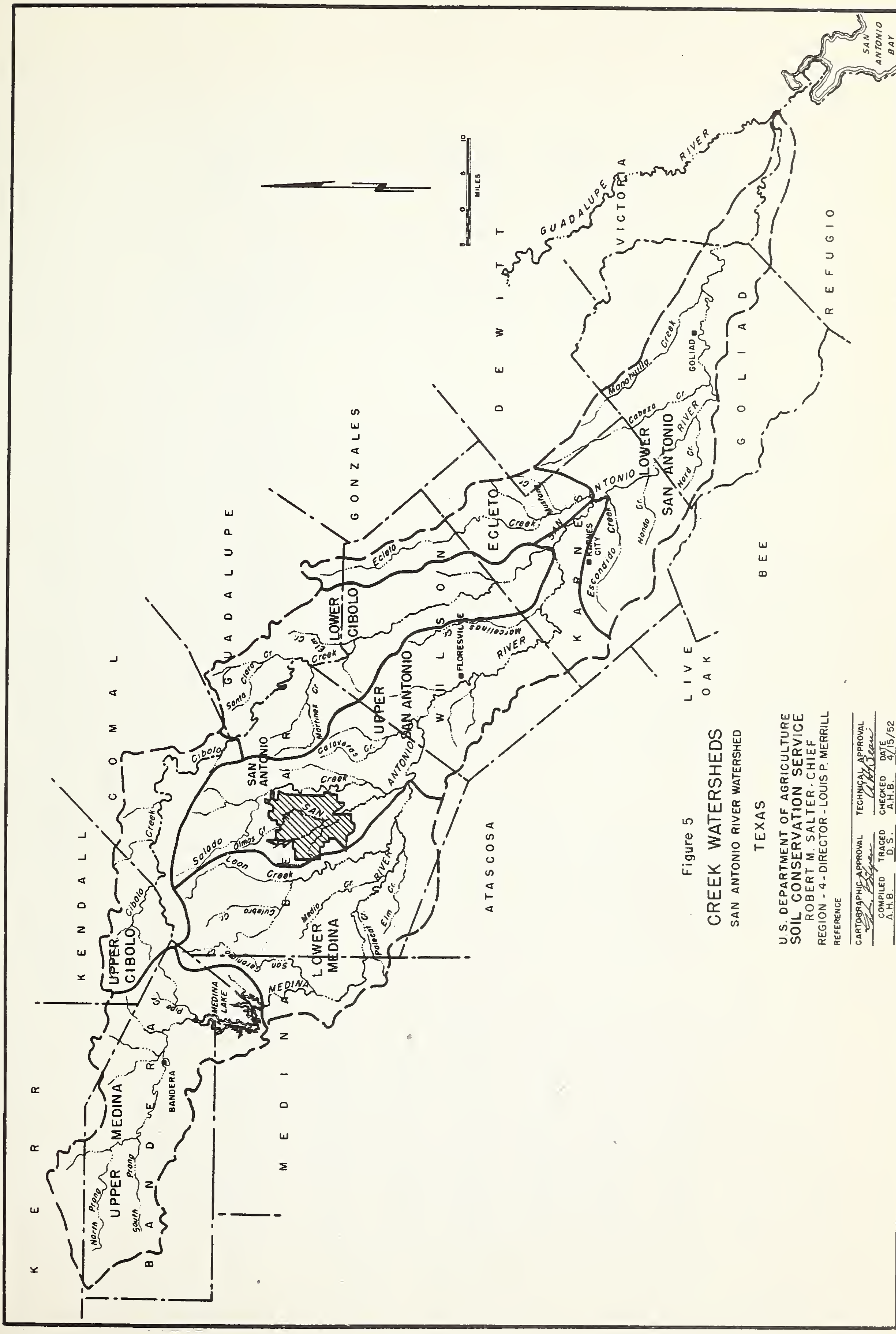

Figure 5

CREEK WATERSHEDS

SAN ANTONIO RIVER WATERSHED

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Table 4. Percent of Various Land Uses by Creek Watersheds

San Antonio River Watershed, Texas

Creek Watershed	Total Area	Non-Farm	Cropland	Grassland	Woodland Pasture	Miscel-laneous
	(acres)	(percent)	(percent)	(percent)	(percent)	(percent)
Upper San Antonio River	637,440	4.19	30.18	64.85	0.21	0.57
Lower San Antonio River	473,600	1.14	28.32	69.74	0.30	0.50
Upper Medina River	405,120	1.20	4.85	92.48	1.37	0.10
Lower Medina River	449,920	8.40	23.40	66.98	0.67	0.55
Upper Cibolo Creek	180,480	2.45	8.87	86.50	2.00	0.18
Lower Cibolo Creek	374,400	3.38	37.88	49.21	8.98	0.55
Ecleto Creek	158,080	1.46	33.19	56.14	8.71	0.50

Table 5. Percent of Various Soil Groups Within Problem Areas in Soil Conservation

San Antonio River Watershed, Texas

Soil Group	Edwards Plateau	Rio Grande Plain	Blackland Prairie	Forested Coastal Plain	Coast Prairie
	(percent)	(percent)	(percent)	(percent)	(percent)
Deep, fine textured soils					
Very slowly permeable	-	5.97	3.58	5.52	66.38
Slowly permeable	13.69	23.65	26.45	14.36	10.84
Permeable	3.83	11.87	20.28	-	-
Deep, medium textured soils					
Very slowly permeable	-	3.97	6.65	23.60	19.04
Slowly permeable	-	15.90	7.23	20.22	-
Permeable	-	6.66	5.59	1.22	-
Deep medium textured soils					
Freely permeable	0.05	1.78	7.92	-	-
Deep, coarse textured soils					
Very slowly permeable	-	0.08	0.34	1.42	-
Slowly permeable	-	6.75	4.43	6.16	-
Permeable	-	1.26	0.47	2.56	-
Freely permeable	-	3.06	0.97	11.29	-
Shallow to very shallow soils	80.25	4.52	4.64	4.14	-
Alluvial soils	0.84	14.42	11.45	9.51	3.74
Rough broken or stony lands	1.34	0.11	-	-	-

Rate of Soil Loss

The Soil Conservation Service has estimated rates of soil loss by erosion within each problem area in soil conservation. The estimated rates for the San Antonio River Watershed are given in table 6. Several characteristics of each unit area (an area having relatively homogeneous physical and economic conditions) were used as bases for estimates of soil loss. The soil loss rates listed were developed from the results of measurements made at agricultural research stations adjusted by the land use pattern, slope gradient and length, storm patterns in the watershed, the interceptive potential of the cover and the agricultural practices now being used.

Rate of Erosion Damage to Land

The annual rate of soil loss is much higher on cultivated lands than on pasture areas. The land use capability of the cropland is being lowered by this soil loss. The following pages discuss this loss of productivity and capability in each problem area in soil conservation.

Edwards Plateau: About 56 percent of the present cropland acreage in the Edwards Plateau problem area in soil conservation is in land use capability class III 1/. This consists of severely eroded areas on gentle slopes or the more steeply sloping land which is severely eroded or subject to rapid erosion under cultivation. In order to maintain these lands at their present level of crop production it is necessary that they receive intensive application of adapted conservation measures.

1/ Class I - Very good land that can be cultivated safely with good farming practices.

Class II - Good land that can be cultivated with a few special practices.

Class III - Moderately good land that can be used regularly for crops but needs intensive practices and treatment.

Class IV - Fairly good land which is best maintained in perennial vegetation but can be cultivated occasionally if handled with care.

Class V - Land not suited for cultivation but can be used for permanent vegetation, grazing and forestry with good management.

Class VI - Land not suited to cultivation and with some hazards and limitations under forest or grazing use.

Class VII - Land not suited to cultivation and with severe hazards and limitations under forest or grazing use.

Class VIII - Land not suited to cultivation, grazing or forest use.

Table 6. Rate of Soil Loss Under Present Conditions by Problem Areas in Soil Conservation and by Creek Watersheds

San Antonio River Watershed, Texas

	Annual Soil Loss Per Square Mile
	(acre-feet)
Problem Area in Soil Conservation	
Edwards Plateau	.44
Blackland Prairie	3.64
Rio Grande Plain	1.07
Forested Coastal Plain	.86
Coast Prairie	.57
Creek Watershed	
Upper San Antonio	1.05
Lower San Antonio	.99
Upper Medina	.43
Lower Medina	.80
Upper Cibolo	.52
Lower Cibolo	.99
Ecleto	1.50 1/

1/ Several areas of Blackland Prairie, too small to show on the Map of Problem Areas in Soil Conservation, raise this rate above the Rio Grande Plain rate.

If soil and water conservation measures are not applied to all lands of this class it is estimated that within approximately 55 years they will have deteriorated to a point where future cultivation will not be profitable or practical.

Approximately 26 percent of the cropland is in class II; 5 percent in class I and the remaining 13 percent in classes IV and VII.

Rio Grande Plain: Approximately 49 percent of the present cultivated land of this problem area in soil conservation is now in capability class III. If farmed for 60 years at the present rate of soil deterioration these lands will change from capability class III to class IV or worse. Class IV land generally is suitable for occassional or limited cultivation.

About 22 percent of the present cropland is in land use capability class II and about the same percentage is in class I. The remaining 7 percent is in class IV, V, VI and VII lands.

Blackland Prairie: This is the most intensively cultivated area in the watershed. Approximately 71 percent of the total land area is in cropland, about 45 percent of which is in land use capability class III. At the present rate of soil decline it is estimated that in 30 to 35 years nearly all of the currently cultivated class III land will be too severely eroded for future cultivation.

Of the remaining cropland, 25 percent is in class II; 21 percent is in class I; and 9 percent in classes IV, V, VI and VII.

Forested Coastal Plain: The Forested Coastal Plain area in the San Antonio River Watershed includes about 15,000 acres of cropland. Approximately 56 percent of the cultivated land is designated as capability class III land. A major portion of this will be changed by erosion to class VI land in about 25 years.

Twenty-nine percent of the cropland in this area is class II land and 5 percent is class I. The remaining 10 percent is in classes IV, V, VI and VII.

Coast Prairie: A very small portion of the San Antonio River Watershed is in the Coast Prairie. Erosion loss is usually minor due to the level surface topography which permits slow movement of runoff waters. About 91 percent of the cropland of this area is in land use capability class I; 8 percent in class III; and 1 percent in classes IV, V, VI and VII.

Sediment Output Rates

Sediment output rates for each problem area in soil conservation were estimated by (1) applying data from the detailed sedimentation survey of Medina Lake made by the Soil Conservation Service in 1948 (2) the use of applicable data from other reservoir sedimentation surveys

outside the San Antonio River Watershed and (3) sediment source studies on small watersheds within each of the various problem areas (4) the rates were checked by use of sediment records on the San Antonio River near Goliad secured by the Soil Conservation Service and the Texas State Board of Water Engineers.

Table 7 shows a comparison between soil loss and sediment output rates by problem areas in soil conservation. Figure 37, Appendix IV shows the estimated sediment contribution rates for floodwater retarding structures in the various sample watersheds studied. Rates of sediment output in these areas vary considerably depending on watershed size. For example, a retarding structure in the Blackland Prairie, with a watershed area of 5 square miles is expected to receive an annual deposit of 2.5 acre-feet per square mile. With a watershed size of 100 square miles, the expected annual deposit would be only 1.4 acre-feet per square mile.

Sedimentation Problems

Edwards Plateau: Since this section is underlain by erosion resistant limestone formations and has a fair cover of brush, trees and grasses the rates of erosion and sediment output are generally low. Damages by accelerated deposition are slight, and channels of most streams are relatively stable and have fairly large capacities. The valley bottoms usually slope strongly toward the channels, which are incising into limestone and shale strata. The chief types of sediment are gravels, which form channel bars, or silt and clay which is transported long distances downstream during floods. Damages by sediment deposition are low. Flood plain scour causes moderate amounts of damage in some cultivated valleys.

Black Prairie: The Black Prairie occupies a comparatively small portion of the watershed but has a higher average erosion rate than any of the physiographic sections represented. Rates of sediment output range from 2 to 5 acre-feet per square mile annually. Most of the area is cultivated and the easily eroded clay soils are readily transported by runoff water. Flood plain land damage resulting from deposition of sediment is small as the material is relatively fertile although some damage is caused by the covering of young plants. Flood plain scour causes moderate amounts of damage and reduces productive capacity as much as 50 percent in some localities although partial or complete recovery of productiveness occurs within a 10-year period on the scoured areas.

South Texas Coastal Plain: The formations in this section consist dominantly of rather poorly cemented sands, silts and clays. Erosion and sediment output rates are high throughout most of the area because of a relatively high percentage of cultivation. Sheet erosion is the main source of sediment, but gully erosion is of importance in a few areas. The channels of the smaller creeks are in many cases partially filled with coarse sediment. Damage from overbank deposition of sediment is usually limited to narrow strips adjacent to the channel. The greater

Table 7. Comparison of Soil Loss and Sediment Output Rates by Problem Areas in Soil Conservation

San Antonio River Watershed, Texas

Problem Area in Soil Conservation	Annual Soil Loss Per Square Mile	Annual Sediment Output Per Square Mile
	(acre-feet)	(acre-feet)
Edwards Plateau	0.44	0.41
Blackland Prairie	3.64	1.55
Rio Grande Plain	1.07	0.85
Forested Coastal Plain	0.86	0.32

part of scour damage occurs in areas where sediment deposition is of minor consequence and causes moderate amounts of land damages.

Coastal Prairie: Damages by sediment deposition, scour and bank erosion are of minor consequence due to the flat topography, low erosion rates and flat stream gradients.

Plant Types

The San Antonio River Watershed contains four main plant associations or plant type areas described below. In general the range conditions are fair to poor with sufficient remnants of the better grasses still present to allow restoration of good conditions through grazing management and brush control.

Hill Country Savanna: This area occupies portions of Kerr, Bandera, Medina, Kendall, Comal and Bexar counties or the Edwards Plateau portion of the San Antonio River Watershed. The original plant cover consisted primarily of bluestem grasses with live oak savanna; little bluestem, big bluestem and sideoats grama being the principal grasses. This area has had a heavy invasion of Texas oak, some cedar and low grade weeds. Bluestem grasses have largely been replaced by inferior plants, such as red grama, threeawns and crotons and the present condition of the range is fair to poor.

Mixed Prairie: A small area of this plant type occurs in east-central Medina and west-central Bexar counties. Original plant cover was primarily sideoats grama, blue sprangletop and feathery bluestems. These grasses have been generally invaded by shrubs of which mesquite and whitebrush are the most prominent.

Present condition of range is fair to poor and the better species of grasses have been replaced by inferior plants such as red lovegrass, red grama, threeawns, crotons, golden crownbeard and perennial plantains.

Coastal Prairie: This plant type area, with the exception of the two narrow bands of post oak savanna in Wilson and Goliad counties, occupies the watershed from the city of San Antonio to the mouth of the San Antonio River.

Original cover consisted primarily of seacoast bluestem, feathery bluestems, tanglehead and blue sprangletop.

Ranges at present are in fair to poor condition and densely covered with mesquite, blackbrush, cenizo and whitebrush. Good grasses, for the most part, have been replaced by red grama, pink pappusgrass and many low grade weeds such as crotons and poorjo.

Post Oak Savanna: Two relatively small areas of Post Oak Savanna cut across the watershed in northern Wilson and southwestern Bexar counties and in Goliad County just north of the town of Goliad.

Original cover was a tall grass savanna in post oak, with some blackjack and live oak. Original grass cover consisted of Indiangrass, big bluestem, switchgrass, seacoast bluestem and tanglehead.

Present ranges are mostly in poor condition and the better grasses have been replaced by low grade perennial grasses and weeds. Some of these are tumble lovegrass, red lovegrass, threeawns, crotons and Yankeeweed.

APPENDIX II.

LAND AND WATER ECONOMY

HISTORY OF DEVELOPMENT

Agricultural development in the watershed began with the founding of the early Spanish missions about 1718 and consisted mainly of small acreages of vegetables and corn used as sustenance crops. Irrigation by diversion from the San Antonio River was practiced at the missions located near the present city of San Antonio. The communities surrounding the San Antonio and Goliad missions existed for nearly 100 years as outposts of civilization in the wilderness of Texas. In 1745 their reports showed 7,115 head of cattle, 3,662 sheep, 664 goats, 257 horses and an annual production of 8,000 bushels of corn, 2,000 pounds of cotton and quantities of beans, melons, pumpkins and other crops. The purpose of the missions was to christianize the Indians, extend the Spanish dominion and establish civil law.

By 1821 the white population did not exceed 7,000 people. The coming of Austin in 1821, with other colonists following him, started Texas on a period of rapid settlement and growth.

A loose system of cattle ranching utilizing the free range was practiced by the early Mexican and American settlers. This with horse raising was the only industry followed. The prairies were covered with tall grasses and furnished year-long feed for the cattle. These conditions continued until after the Civil War when cattle numbers had increased greatly because of favorable weather and lack of markets. As cattle became too numerous the pastures began to deteriorate and cattle were slaughtered for their hides and tallow which could be marketed at New Orleans. After this period the great cattle drives to northern railheads began and continued until railroads were built into Texas.

General farming began to expand in the latter part of the nineteenth century and cotton and corn, were grown almost to the exclusion of all other crops. Many of the large ranch holdings were subdivided into farms and the herds moved westward. However there still are a number of large ranches near the lower part of the San Antonio River Watershed. The advent of the boll weevil at the beginning of the twentieth century caused a great decrease in cotton acreage and production of other crops such as peanuts, peas, sweet potatoes, sorghums and some fruits and vegetables was increased.

The breaking up of the larger tracts of land and cultivation of land acreages of cotton after the Civil War contributed to soil erosion. By the turn of the last century erosion was beginning to be a serious problem on sloping land. The use of legumes and commercial fertilizers dates from this period.

The crops grown and type of farming now followed depends upon the soils present on the individual farms. Peanuts and sweet potatoes are grown on the sandy soils while corn, sorghum, flax, oats and cotton are grown chiefly on the heavier soils. The rougher, sandy and low areas are usually used for grazing.

The growth of San Antonio during and after World War II has created a great demand for fluid milk. A large number of dairies have been established because of this demand. The high price of beef has stimulated interest in pasture improvement and the irrigation of grass and feed crops.

POPULATION

The total population of the San Antonio River Watershed in 1950 was 540,438, an increase of 157,640, or approximately 29 percent, during the period 1940 to 1950, table 8.

The urban population of the watershed was 502,851 in 1950, an increase of 240,406 from the 1940 urban population. There were 3 urban communities (cities having a population of 2,500 or more) within the watershed in 1950 compared with 2 such communities in 1940 and 1930. The largest increase occurred in the metropolitan area of San Antonio when in 1950 the population was 406,811 within the city limits and 496,090 in the metropolitan area. The other cities were Kenedy, population 4,177 and Karnes City, population 2,584.

Rural Population

The rural population of the watershed was 120,353 in 1940 as compared with 37,587 in 1950. This decrease was caused to a large extent by the inclusion of the heavily populated area surrounding San Antonio into the metropolitan area.

CHANGES IN FARM VALUE AND SIZE

Changes in farm values usually reflect, after a lapse of a few years, fundamental changes which have taken place in the financial status of farming.

From 1930 to 1940 land values in all areas of the watershed declined sharply as shown in table 9. This decline reflected the depressed condition of farming during this period which had forced many farmers to adopt an exploitative system of farming. This exploitation accelerated erosion and by producing conditions favorable to increased runoff increased the flood hazards. Since 1940, farm values and incomes have increased rapidly as shown in table 10 and farmers now have less difficulty in meeting fixed expenses and have more freedom of choice in organizing their farm enterprises. They are in a better financial position to adjust their businesses to meet any decline in prices of farm products or to increase the efficiency of farm operations.

Table 8. The Approximate Rural Farm, Rural Non-Farm and Urban Population, 1930-1950 1/

San Antonio River Watershed, Texas

Item	Population Census of						Percent Change	
	1930		1940		1950*		1930-1940	1940-1950
	(number)	(percent)	(number)	(percent)	(number)	(percent)		
Rural Farm	56,803	16.6	50,132	13.1	2/	2/	-11.76	2/
Rural Non-Farm	45,578	13.3	70,221	18.3	2/	2/	+54.07	2/
All Rural	102,381	29.9	120,353	31.4	37,587	6.95	+17.55	-68.77
Urban	240,734	70.1	262,445	68.6	502,851	93.05	+ 9.02	+91.60
Grand Total	343,115	100.0	382,798	100.0	540,438	100.0	+11.57	+29.17

1/ Adapted from U. S. Census

2/ Not available.

* 1950 Texas Almanac.

Table 9. Average Value of Farmland and Buildings Per Acre of Farmland in Each Problem Area in Soil Conservation

San Antonio River Watershed, Texas

Problem Area in Soil Conservation	Average Value per Acre, Census of		
	1930 1/	1940 1/	1950 2/
	(dollars)	(dollars)	(dollars)
Edwards Plateau	24.14	20.42	52.22
Blackland Prairie	104.70	52.27	102.85
Forested Coastal Plain	41.72	21.09	41.28
Rio Grande Plain	58.88	31.65	69.50
Coast Prairie	34.96	23.56	47.76
Median Average for All Problem Areas in Soil Conservation	52.88	29.80	62.72

1/ Averages for problem areas in soil conservation are derived from representative minor civil division data, U. S. Department of Commerce, Census of Agriculture, 1930 and 1940.

2/ Adapted from U. S. Census of Agriculture, 1950 (preliminary data).

Table 10. Average Value per Farm of Farmland and Buildings for Each Problem Area in Soil Conservation

San Antonio River Watershed, Texas

Problem Area in Soil Conservation	Average Value per Farm, Census of		
	1930 1/ (dollars)	1940 1/ (dollars)	1950 2/ (dollars)
Edwards Plateau	14,379	10,035	29,463
Blackland Prairie	8,533	5,839	14,276
Forested Coastal Plain	5,615	3,912	9,565
Rio Grande Plain	8,697	5,745	17,953
Coast Prairie	13,749	14,457	32,760
Median Average for All Problem Areas in Soil Conservation	10,195	7,998	20,803

1/ Averages for problem areas in soil conservation are derived from representative minor civil division data, U. S. Department of Commerce, Census of Agriculture, 1930 and 1940.

2/ Adapted from U. S. Census of Agriculture, 1950 (preliminary data).

Size of Farms

The average size of farms has been increasing in the watershed, as shown in table 11. The increase has been general in all areas except in the Edwards Plateau problem area in soil conservation.

The increases in farm values and size of farms are in the direction of a more stable agricultural economy in the watershed and will assist in the installation of the recommended program.

LAND OWNERSHIP

Most of the land of the watershed is privately owned. Publicly owned lands include several U. S. Military Reservations, and municipally owned acreages. About 96.5 percent of the land area is in farms.

In all calculations involving acreage the non-farmland estimates made by the Soil Conservation Service in the Conservation Needs Inventory (unpublished records) were used. These estimates were made for small areas and are considered a more nearly correct determination of the acreage of treatable lands than can be derived from census data, table 12.

TENANCY

In 1930 about 36.9 percent of the farmland in the watershed was operated by tenants, but by 1950 this percentage had declined to 8.4 percent as shown in table 13. Most of the part owner operated land, which is essentially tenant operated, is evidently rented to round out a unit. It is probable that most in this class have better equipment and more adequate capital than the tenant operators.

These data become important when consideration is given to the fact that land uses and farming practices on tenant-operated farms are often conducive to accelerated erosion and increased water losses from the farm. Tenants use their farmland more intensively than owner operators and are less inclined to cooperate in conservation programs designed to reduce soil loss and runoff. Therefore, the decrease in tenancy will facilitate obtaining farmer cooperation in installing the recommended program.

LAND USE

Figure 6 shows the intensity of use for which each area is suited and the intensity of treatment needed to prevent further decline in productivity. These lands can support a permanent agriculture of the type recommended, provided the proposed type of use and treatments are adopted with reasonable promptness. Otherwise, severe damage from erosion may occur to the remaining land resources.

Table 11. Average Size of Farm for Each Problem Area in Soil Conservation

San Antonio River Watershed, Texas

Problem Areas in Soil Conservation	Average Size of Farm, Census of		
	1930 1/	1940 1/	1950 2/
	(acres)	(acres)	(acres)
Edwards Plateau	595.6	491.5	564.2
Blackland Prairie	81.5	111.7	138.8
Forested Coastal Plain	134.6	185.5	231.7
Rio Grande Plain	147.7	181.5	258.3
Coast Prairie	393.3	613.5	685.9
Median Average for All Problem Areas in Soil Conservation	270.5	316.7	375.8

1/ Averages for problem areas in soil conservation are derived from representative minor civil division data, U. S. Department of Commerce, Census of Agriculture, 1930 and 1940.

2/ Adapted from U. S. Census of Agriculture, 1950 (preliminary data).

Table 12. Percent of Land in Farms for Each Problem Area in Soil Conservation 1/

San Antonio River Watershed, Texas

Problem Areas in Soil Conservation	Land in Farms, Census of		
	1930	1940	1950
	(percent)	(percent)	(percent)
Edwards Plateau	97.4	95.4	97.6
Blackland Prairie	76.4	78.0	78.5
Forested Coastal Plain	71.6	78.4	82.0
Rio Grande Plain	74.7	76.5	84.0
Coast Prairie	139.7 2/	100.6 2/	88.4

1/ Adapted from U. S. Census of Agriculture, 1930, 1940 and preliminary data for 1950.

2/ The excess of farm acreage over land area is due to the fact that the entire acreage of a farm is tabulated as being in the county or civil division in which the headquarters is located, even though a part of the farm may be situated in an adjoining county or civil division.

Table 13. Percent of Farmland Operated Under Each Type of Tenure 1/

San Antonio River Watershed, Texas

Tenure of Operator by Problem Areas in Soil Conservation	Farmland, Census of 1930 (percent)	1940 (percent)	1950 (percent)
Edwards Plateau			
Owner	58.4	56.5	64.5
Part Owner 2/	8.5	17.7	22.2
Manager	8.6	5.9	10.6
Tenant	24.5	19.9	2.7
Total	100.0	100.0	100.0
Blackland Prairie			
Owner	37.8	40.2	58.6
Part Owner	7.8	20.7	29.3
Manager	1.6	1.2	0.7
Tenant	52.8	37.9	11.4
Total	100.0	100.0	100.0
Forested Coastal Plain			
Owner	42.6	41.6	56.9
Part Owner	8.8	21.1	31.5
Manager	5.0	1.4	1.3
Tenant	43.6	35.9	10.3
Total	100.0	100.0	100.0
Rio Grande Plain			
Owner	43.4	41.0	54.5
Part Owner	9.4	20.7	32.8
Manager	4.3	5.5	3.1
Tenant	42.9	32.8	9.6
Total	100.0	100.0	100.0
Coast Prairie			
Owner	36.2	24.9	56.5
Part Owner	35.0	40.2	34.8
Manager	7.9	16.5	1.0
Tenant	20.9	18.4	7.7
Total	100.0	100.0	100.0
Total Watershed			
Owner	43.7	40.8	58.2
Part Owner	13.9	24.1	30.1
Manager	5.5	6.1	3.3
Tenant	36.9	29.0	8.4
Total	100.0	100.0	100.0

1/ Adapted from U. S. Department of Commerce, Census of Agriculture, 1930, 1940 and preliminary data for 1950. 2/ Land rented from others by farm operators and considered tenant operated.

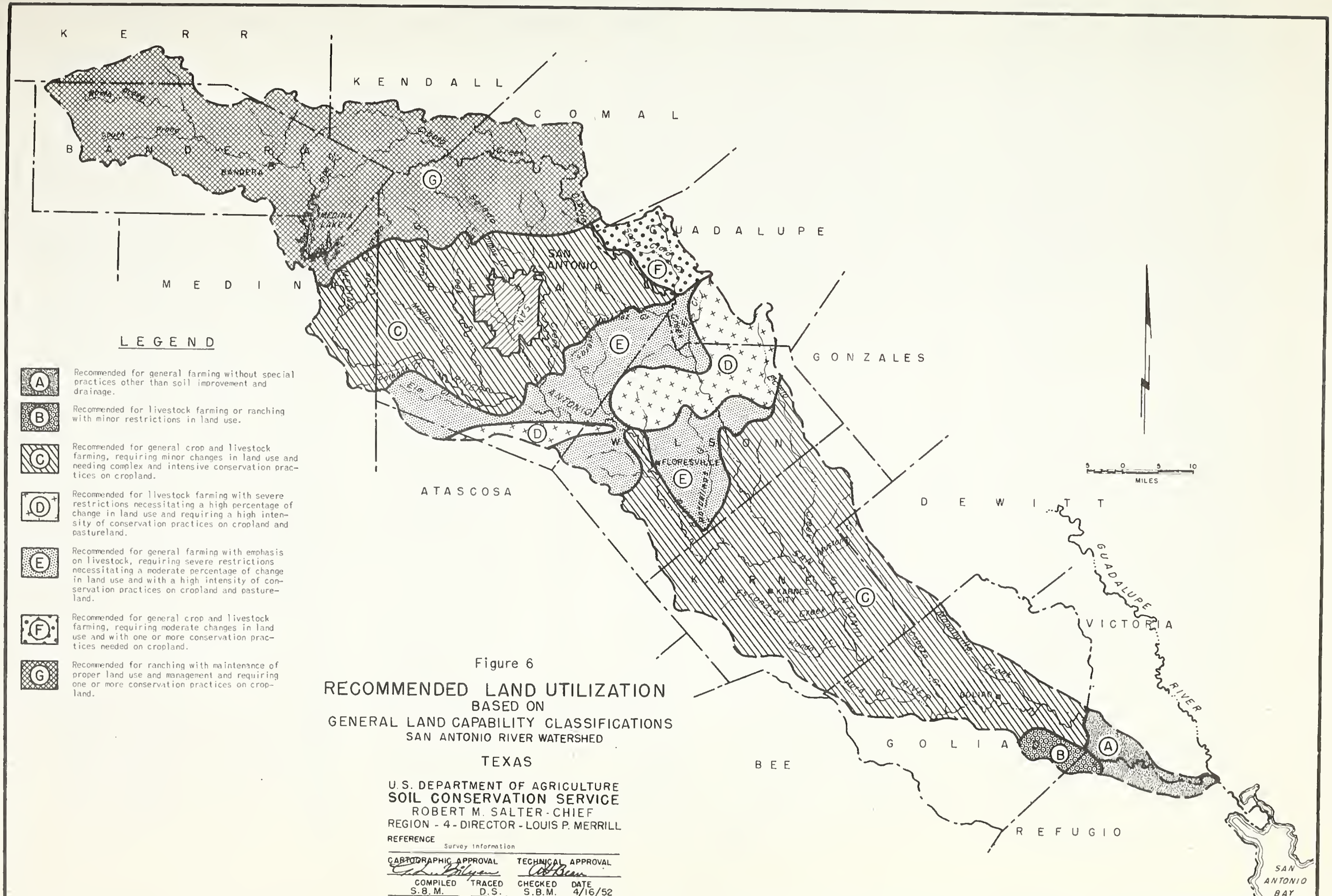

Figure 6

RECOMMENDED LAND UTILIZATION
BASED ON
GENERAL LAND CAPABILITY CLASSIFICATIONS
SAN ANTONIO RIVER WATERSHED

TEXAS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION - 4 - DIRECTOR - LOUIS P. MERRILL

REFERENCE Survey information

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
COMPILED	TRACED	CHECKED	DATE
S.B.M.	D.S.	S.B.M.	4/16/52

4-R-8222-32

D S 9/5/51 4-R-8222

SOIL CONSERVATION

The Department of Agriculture through its several agencies and in cooperation with State and local organizations is currently assisting land owners and operators in the application of measures which are deemed of primary importance to the objectives of the Flood Control Act. Additional discussion is found in Appendix V.

State interest in soil conservation has been demonstrated by passage of legislation providing for the formation of soil conservation districts and by the appropriation of funds for their use. Thirteen districts have been organized in or adjacent to the watershed and include the entire watershed area within their boundaries, figure 7.

RESERVOIRS, LEVEES AND OTHER IMPROVEMENTS

A large irrigation reservoir on the Medina River was constructed in 1911-1913 and is owned by the Bexar-Medina-Atascosa Counties Improvement District No. 1. The reservoir, with a constructed capacity of 274,000 acre-feet, supplies a system of canals and laterals which service 34,500 acres within the Improvement District, of which 13,200 acres is in the San Antonio River Watershed. Since its construction, this reservoir has reduced all flood flows on the Medina River immediately below the dam to non-damaging proportions.

Olmos dam, above San Antonio Springs and the city, is a flood control reservoir which is operated to reduce damages within the city. There are several private levees near the mouth of the river for local protection on the McFaddin and Austin Estates.

The Department of the Army, Corps of Engineers, has prepared a survey report 1/ which recommends the following:

1. A channel improvement project through the city of San Antonio, Texas. This includes the San Antonio River from Bergs Mill to East Hildebrand Street (11.6 miles) and a total of 31.0 miles of channel on San Pedro, Apache, Alazan and Martinez Creeks as well as relocation and construction of channel dams and modification of bridges.

2. A channel improvement project through the town of Kenedy, Texas on Escondido Creek. This includes improvement of about 2.1 miles river channel and bridge modification.

INDUSTRIES

There are numerous business enterprises in the watershed closely associated with agriculture; cotton gins and compresses, grain elevators,

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1/ Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas, October, 1950, Unpublished.

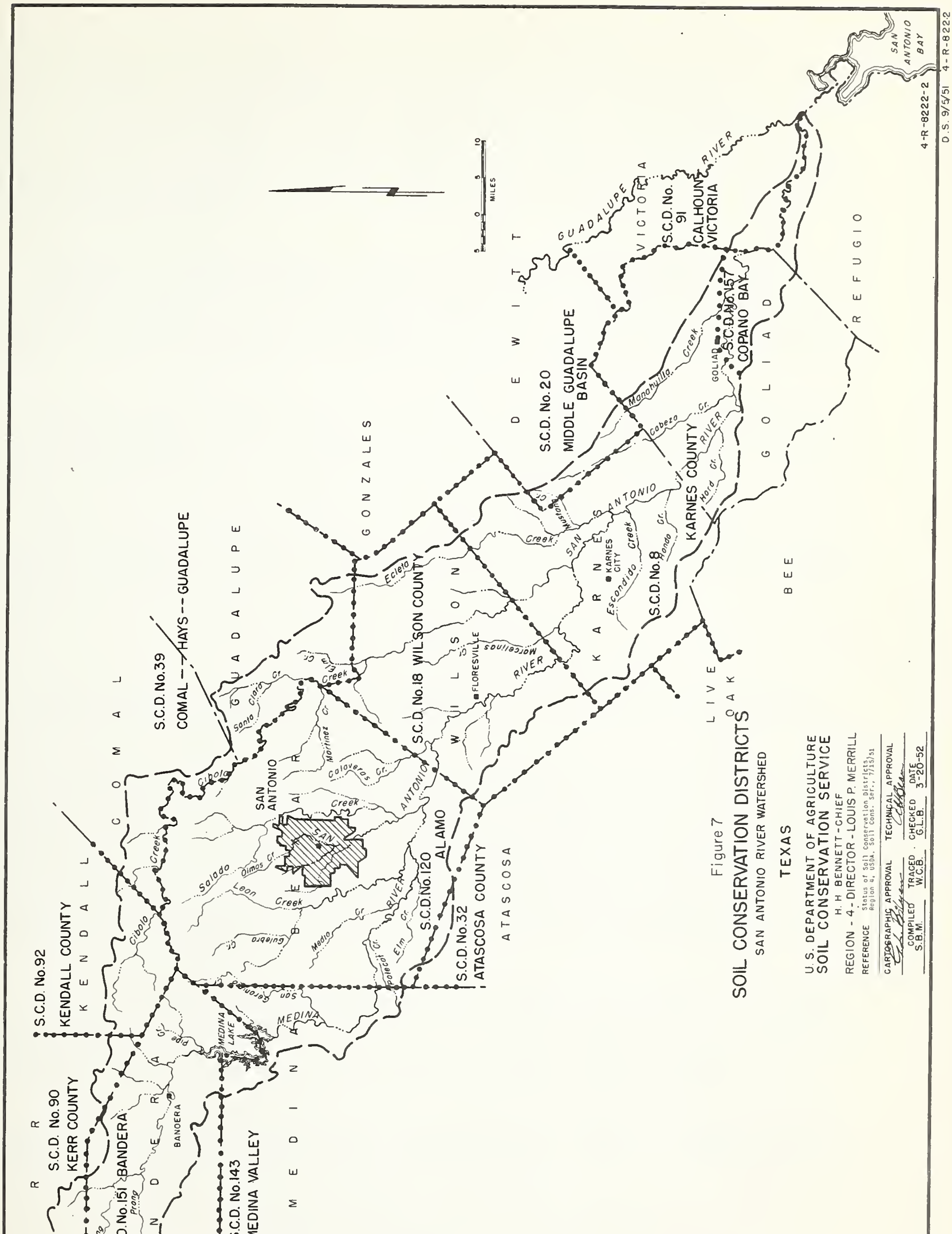

Figure 7
SOIL CONSERVATION DISTRICTS
SAN ANTONIO RIVER WATERSHED
TEXAS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H BENNETT-CHIEF
REGION - 4 - DIRECTOR - LOUIS P. MERRILL
REFERENCE Status of Soil Conservation Districts, Region 4, USDA, Soil Cons. Ser., 7/15/51

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL
COMPILED S.B.M.	TRACED W.C.B.	CHECKED G.L.B.	DATE 3-20-52

oil mills and various types of food processing plants. These have a major effect on the economy of the watershed. Vegetable production near San Antonio and specialty seed production are increasing in importance. Over 4,200 acres of guar, hubam sweetclover, blue panicgrass, K. R. bluestem, buffelgrass and yellow sweetclover was grown for seed in 1951 and an increase of 18,000 acres is expected for 1952. Growing, harvesting, processing and merchandising of this production is becoming an important industry.

The total production of crude oil in the watershed was estimated at 3,278,762 barrels in 1950. This industry has been developing since 1889 and the annual value of the production was approximately $8,000,000 in 1950. Accessory pipelines, pumping plants, and refineries contribute to the economic development of the watershed.

Various other industries of importance are the manufacture and distribution of brick, tile, pottery, cement, building stone, furniture, refrigeration equipment and various other items. San Antonio is a very important wholesale and retail outlet in the state of Texas.

Four railroad companies serve the watershed with main and branch lines and a network of roads, power lines, pipelines and airlines extend throughout the watershed.

NATURAL RESOURCES

Many deposits of various sands, clays, gravel, stone and lignite remain to be utilized in the watershed.

The watershed north and west of San Antonio is in the famous "Hill Country" which abounds with deer, turkey, squirrels and doves and has a reasonable supply of ducks, quail and fur bearing animals. During the deer hunting season thousands of hunters hunt for game on the ranches on which they rent hunting privileges. The lease income and the amount spent by hunters for travel, recreation and subsistence within the watershed is an important source of income to the ranchers and business men of the watershed.

Near Bandera there are numerous guest ranches developed to provide vacation spots during the summer season. Several lakes with good fishing are available and the natural beauty of the cedar hills, cypress-lined creeks and rugged topography make this a popular vacation area.

The tourists visiting the historic shrines in the watershed and the vacationers and hunters contribute substantially to the economy of the watershed through increased business and income.

MILITARY ESTABLISHMENTS

There are several military training centers and other establishments within the watershed near San Antonio. The United States Air Force

operates Randolph, Brooks, Kelly and Lackland bases The United States Army operates Camps Stanley and Bullis in the Leon Springs Military Reservation and Fort Sam Houston and Camp Normoyle in San Antonio.

GROUND WATER RESOURCES

General Relationships of Water Supply

An adequate water supply is the basic requirement for agricultural, urban and industrial development. When the water supply is limited in quantity or is of unsatisfactory quality the development of an area is hindered.

In the San Antonio River Watershed surface water supplies are moderate in quantity and, except for Medina Lake, have been developed only to a limited extent. The availability of unusually large quantities of ground water, however, has made possible the great municipal and industrial growth of San Antonio, the development of several large military bases, and extensive use of water for farms, ranches and irrigated land. The Edwards Plateau and a belt of country below it and parallel to the Balcones Escarpment constitute one of the most productive ground water provinces in Texas. Furthermore, a number of aquifers in the Gulf Coastal Plain downstream from San Antonio furnish sufficient water for nearly all local farm and municipal requirements.

Principal Aquifers

Travis Peak Formation: The Travis Peak formation at the base of the Trinity group of Lower Cretaceous age does not appear at the surface anywhere in the watershed. Two productive wells in the Travis Peak sands, however, furnish an adequate municipal water supply for the town of Bandera in Bandera County 1/. It is reported that these sands contain large supplies of water under artesian pressure beneath much of the northern part of the watershed, but in most places they occur at depths too great to be used for ordinary water wells.

Edwards and Glen Rose Formations: The Glen Rose formation of Lower Cretaceous (Comanchean) age overlies the Travis Peak sands. Its surface outcrop occupies most of the Edwards Plateau area in the watershed, since much of the overlying Edwards limestone has been removed by erosion. Its thickness, as reported from measurements of outcrops and well logs, ranges from 500 to 1,200 feet 2/. Alternating beds of marly or argillaceous limestone and nodular limestone characterize the formation throughout its thickness. Therefore, its permeability generally

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1/ Broadhurst, W. L., Sundstrom, R. W., and Rowley, J. H., "Public Water Supplies in Southern Texas," Texas Bd. of Water Engrs. & U.S.G.S., 1946.

2/ Sayre, A. N., Geology and Ground Water Resources of Uvalde and Medina Counties, Texas, U.S.G.S. Water Supply Paper 678, 1936.

is low to moderate. In most places on the plateau it yields small water supplies to wells at depths of 100 to 500 feet. Many farms and ranches obtain water from wells yielding from 5 to 20 gallons per minute. In some places, however, especially near Cibolo Creek along the Comal-Bexar County line, the Glen Rose is cavernous and is locally important as an aquifer 1/. It is shown by George, from Weather Bureau records of a 6.29-inch rainfall which occurred in August 1946 at Bulverde, Randolph Field, Boerne and New Braunfels, that a discharge of 300 second feet resulted in Cibolo Creek near the northwest corner of Bexar County. Yet none of this water reached the Bulverde station. It was absorbed into the cavernous Glen Rose limestone and probably reached deep ground water zones. Most of the productive wells in the Bulverde area and in extreme northern Bexar County derive water from the Glen Rose.

The Edwards limestone, overlying the Glen Rose and separated from it by the thin Walnut clay and Comanche Peak limestone members, is the most important aquifer in the drainage area. It has been displaced downward several hundred feet by faulting along the plateau margin so that its surface is at a lower elevation than that of the Glen Rose in the vicinity of Medina Lake. The Edwards is a massive crystalline limestone formation which is much harder and more brittle than the Glen Rose, and is extensively fractured, jointed and cavernous in the Balcones fault zone. The numerous cavities and solution channels add greatly to the permeability of the formation.

Large springs issuing from the lower part of the escarpment from near Austin to Uvalde are especially productive at San Marcos, New Braunfels and San Antonio. The Comal Springs at New Braunfels have maintained an average flow of 323 1/ cubic-feet per second for a period of more than 20 years. This is equivalent to 235,000 acre-feet per year. A spring on Honey Creek 7 miles northwest of Bulverde, which flows from the base of the Glen Rose formation, has a discharge of 1,000 to 1,500 gallons per minute. When New Braunfels, San Antonio and a number of smaller communities were established they were located at or near the springs to utilize the abundant water supply.

At San Antonio the San Pedro and San Antonio springs have produced a large and reliable flow from a time long before discharge records were available. The surface of the Edwards formation in the San Antonio area is buried beneath younger rocks at depths ranging from 400 to 1,000 feet 2/. Water under hydrostatic pressure from higher areas to the northwest is forced upward through fault fractures and cracks in the overlying formations to the springs. During the development of San Antonio a large number of wells have been drilled for private and industrial use, hotels and other buildings and municipal water supply. Many of these wells had spontaneous

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1/ George, W. O., Geology and Ground Water Resources of Comal County, Texas, Texas Bd. of Water Engrs. and U.S.G.S., 1947.

2/ Livingston, Penn, Sayre, A. N., and White, W. N., Water Resources of the Edwards Limestone in the San Antonio Area, Texas, U.S.G.S., Water Supply Paper 773 B, 1936.

flow when drilled, and in others the water stood near ground surface. Continuous heavy pumping and variation in rainfall in the contributing area now cause water levels to fluctuate considerably. Pumping alone, however, during periods of average rainfall causes relatively little draw-down. The drought of 1949-51, together with increased city water consumption, had reduced the water levels in the San Antonio municipal wells to unusually low levels at the beginning of 1952.

So productive is the Edwards formation that 62 million gallons of water per day were pumped throughout the year 1949 for the city of San Antonio, and about 30 million gallons per day were pumped for irrigation in Bexar and Medina counties during the same period 1/. The San Antonio Springs at the head of the San Antonio River in the northern part of the city have produced a maximum flow of 20 cubic-feet per second for a 3-week period (November 1919), 2/ but this spring has had a number of periods of no flow, depending upon variations in artesian pressure in the underground Edwards reservoir. The San Pedro Springs at the head of San Pedro Creek in the north-central part of the city have produced a maximum discharge of about 18 cubic-feet per second 2/. This flow was measured a short distance downstream on San Pedro Creek and probably included about 4.3 cubic-feet per second from flowing wells in the area.

The estimated total yield of the San Antonio and San Pedro Springs and all wells in the county taken from the Edwards limestone was about 155 million gallons per day for the year 1946 3/. Many flowing wells in the city and on farms and ranches in the county are not capped, but are permitted to flow freely when not in use. When the San Antonio Springs are not flowing, the discharge of about 10 large artesian wells in the vicinity contributes about 15 cubic-feet per second to maintain the flow of the river. An artesian well of the San Antonio Public Service Company near Roosevelt Park had a measured natural flow of 23.9 million gallons per day in 1941 soon after it was drilled.

Authorities have estimated that the losses from surface stream flow alone to the underlying limestone reservoir in the Balcones fault zone are at least 150,000 acre-feet annually 3/. This figure includes the Medina, Frio, Dry Frio, Nueces, and Sabinal rivers and Hondo Creek. This probably is a relatively small part of the total supply in the underground reservoir when rainfall on the large area of outcrop and the resultant ground water movements are considered.

South of southern Bexar County the Edwards formation is buried too deeply and usable supply is too uncertain to favor practical water well development and ground water is obtained from younger rock formations.

1/ White, W. N., Nineteenth Report, Texas Board of Water Engineers, . September 1948 to September 1950, November 1950.

2/ Livingston, Penn, Ground Water Resources of Bexar County, Texas, Texas Bd. of Water Engrs., and U.S.G.S., May 1947.

3/ Livingston, Penn, Sayre, A. N. and White, W. N., Water Resources of the Edwards Limestone in the San Antonio Area, Texas U.S.G.S. and Texas Board of Water Engrs. Water Supply Paper 773-B, 1936.

<u>The Washita Group and Upper Cretaceous Formations</u>: Only meager ground water supplies are recovered from these formations and much of this is highly mineralized. Usually these formations are not developed by drillers and the Edwards Limestone below is used for water supplies.

<u>Tertiary Formations</u>: At least 7 sandy formations of Tertiary age yield moderate to large ground water supplies in the West Gulf Coastal Plain section of the San Antonio River Watershed. The Tertiary and Quaternary formations dip gently toward the Gulf at angles slightly greater than the slope of the land surface. This large system of sedimentary rocks consists of alternating permeable and less permeable formations which have wide belts of surface outcrop in an area of moderate rainfall (30 to 35 inches annually) 1/. Therefore the characteristics of an artesian ground water system are present.

<u>Midway and Wilcox Formations</u>: The Midway formation, which consists chiefly of clays and sandy clays, has low permeability and no importance as a water bearing formation. The Wilcox formation is lenticular in bedding and has highly mineralized water in places. It supplies water to a number of wells 50 to 200 feet deep within its outcrop area but is not a highly productive or reliable aquifer.

<u>Clairborne and Jackson Groups</u>: Several sands in the Claiborne group, including the Carrizo, Mount Selman, Queen City, Cook Mountain and Sparta formations, yield ground water for municipal supply, farm and ranch wells and irrigation in this area. Wells ranging from 300 to 2,000 feet deep yield municipal water supplies for Floresville, Poth, Stockdale and other smaller communities. Artesian flow of nearly 400 gallons per minute is reported for some of these wells, and Floresville uses 300,000 gallons per day 2/. The Carrizo sand is generally the best aquifer but the other sands in the group also are important locally.

The Jackson formations include some sands which yield water to wells within the outcrop area.

<u>Miocene Formations</u>: The Catahoula sandstone and tuff and the Oakville sandstone have relatively good permeability, and furnish reliable ground water supplies in their area of outcrop and southeastward beneath younger formations. The Lagarto has low permeability and only minor importance as an aquifer. Municipal wells at Runge, Kenedy and Karnes City range from 200 to 860 feet in depth and produce water from sands in the Catahoula and Oakville formations. Kenedy, the largest town in the area, pumps about 500,000 gallons per day from 3 wells.

<u>Pliocene and Pleistocene Formations</u>: In a strip of Coastal Prairie about 25 miles wide along the Gulf Coast ground water supplies are obtained from the Goliad formation (Pliocene) and Lissie and Beaumont formations (Pleistocene). Both the Goliad and the Lissie have considerable

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1/ Deussen, A., Geology of the Coastal Plain of Texas West of the Brazos River, U.S.G.S. Prof. Paper 126, 1924.

2/ Broadhurst, W. L., Sundstrom, R. W., and Rowley, J. H., Public Water Supplies in Southern Texas, Texas Bd. of Water Engrs. and U.S.G.S., 1946.

thicknesses of sand and gravel which serve as reliable aquifers for municipal water, and farm and ranch wells. It is believed that water for additional irrigation and industrial enterprises could be developed from these formations in the lower watershed. Goliad and a number of smaller communities in Goliad County pump water for municipal use. Two wells 325 and 461 feet deep at Goliad supply 100,000 gallons per day for the town.

The Beaumont formation, although chiefly clay, has some sand strata which yield small water supplies.

Ground Water as Related to the Recommended Program

Abundance of Ground Water Resources: The San Antonio River Watershed as a whole has unusually large and well distributed ground water supplies. Despite the heavy draft of about 150 million gallons per day in the San Antonio area and northern Bexar County, additional expansion of ground water use seems feasible in that area. Even in areas underlain by rocks of less permeability, such as the Glen Rose limestone on the Edwards Plateau upland and the area of Upper Cretaceous rocks, water supplies generally are adequate, and increased yields can be obtained by deeper drilling. Most of the Coastal Plain section has sufficient ground water reserves to permit greater than present development of municipal use, industrial use and irrigation. Areas supplied by the principal aquifers are shown on the Ground Water Map, figure 8, and data on typical wells are tabulated in table 14.

The geologic and physiographic situation is such that artesian conditions prevail throughout most of the drainage area. The high plateau underlain by limestones, the channeled and fractured Edwards formation, the extensively faulted Balcones Escarpment and the gently dipping Tertiary-Quaternary formations of alternately permeable and less permeable sediments are all favorable factors to good ground water availability. The potentially productive alluvial sands and gravels of the lower valley are subject to very little water use, and Falls City is the only town of consequence which uses river water.

Quality of Water: Most of the ground waters are of relatively good quality. Water from the channeled Edwards limestone along the Balcones Fault zone and northern Bexar County is of excellent quality and contains an average of only about 100 to 300 parts per million of dissolved solids. It is used extensively for municipal and industrial supply, local farm and ranch supply and irrigation. The farm and ranch wells in the Glen Rose formation on the Edwards Plateau upland supply water which is slightly to moderately mineralized and hence is usable for nearly all purposes. In the Coastal Plain the ground waters from the Tertiary and Quaternary formations have a wide range in quality. Many wells such as those at Floresville, Saspamco and Kenedy contain 1,000 parts per million, or more, of dissolved solids. They are generally suitable for municipal use, farm and ranch wells and certain types of industrial use, but they are poor or unsuitable for irrigation. Water from the wells of any one formation is apt to have a wide range in quality. Some wells may be suitable for

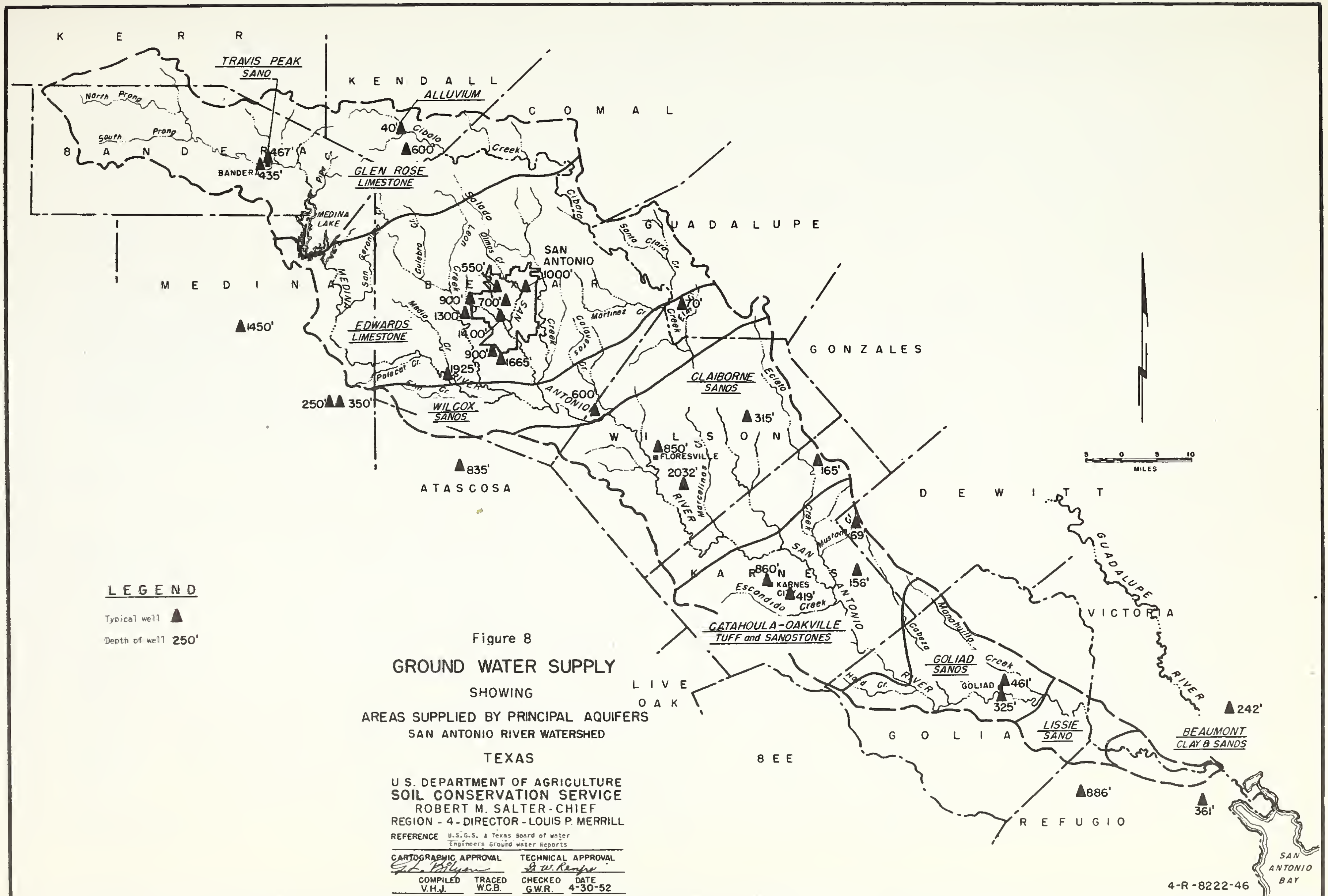


Figure 8

GROUND WATER SUPPLY

SHOWING

AREAS SUPPLIED BY PRINCIPAL AQUIFERS

SAN ANTONIO RIVER WATERSHED

TEXAS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION - 4 - DIRECTOR - LOUIS P. MERRILL

REFERENCE U.S.G.S. & Texas Board of Water Engineers Ground Water Reports

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
G. L. Bilyeu		G. W. Renfro	
COMPILED	TRACED	CHECKED	DATE
V.H.J.	W.C.B.	G.W.R.	4-30-52

Table 14. Typical Wells in Chief Aquifers - San Antonio River Watershed, Texas

Location	Depth (feet)	Aquifer	Use	Water Yield (gal./min.)	Irrigation Quality	Remarks
Bandera	467	Travis Peak	Municipal	26	Good	
San Antonio						
1 Mi. N. Vanormay	1,925	Edwards	Irrigation	3,700	Excellent	Artesian
Alamo Heights	550	Edwards	Municipal	300	Good	
Breckenridge Park	700	Edwards	Municipal	2,800	Good	
Los Angeles Heights	1,000	Edwards	Municipal	1,400	Good	
W. Edge City Limits	1,300	Edwards	Irrigation	1,700	Good	
S. Edge City Limits	1,665	Edwards	Irrigation	3,000	Excellent	
Boerne	40	Recent Alluvium	Municipal	210	Good	
Floresville	850	Carrizo	Municipal	375	Unsuitable	
Saspamco	600	Wilcox	Commercial	33	Unsuitable	High in dissolved solids
Stockdale	315	Queen City	Municipal	93	Fair	
Karnes City	860	Catahoula	Municipal	60	Unsuitable	Over 1,000 ppm dissolved solids
Kenedy	419	Oakville	Municipal	277	Unsuitable	Over 1,000 ppm dissolved solids
Goliad	325	Goliad	Municipal	500	Poor	
Refugio	886	Goliad	Municipal	330	Unsuitable	
Port Lavaca	242	Lissie	Municipal	300	Unsuitable	
Austwell	361	Beaumont	Municipal	30	Unsuitable	

irrigation while others may be doubtful or unsuitable. Most of the wells in the lower Coastal Plain at localities such as Karnes City, Goliad and Port Lavaca yield water which is generally potable but questionable as an irrigation supply.

Relationships to Rainfall and Runoff: As in all ground water systems the water yield from wells throughout the drainage area shows some response to heavy withdrawal and to variations in rainfall. The highly permeable limestones of the Edwards Plateau system show immediate and substantial increase following periods of rainfall. The granular formations of the Coastal Plain show a slower response to rainfall on the areas of outcrop, but the draft on these formations has not yet been developed to a point near their potential yield.

It seems probable that erosion control and conservation measures planned for the Edwards Plateau will have slight effect upon recharge of underlying aquifers. The soils are thin, areas of bare rock slopes are extensive and downward percolation into the underlying limestones probably is not subject to substantial modification. On outcrop areas of the sandy aquifers of the Gulf Coastal Plain some increases in downward percolation of water from rainfall will result from improved vegetal cover and erosion control and waterflow retardation structures. This factor has been evaluated in Appendix VII.

APPENDIX III

HYDROLOGY

GENERAL METHODOLOGY

Reductions in runoff and area flooded in the San Antonio River Watershed were determined by the procedures described on the following pages.

In the study of rainfall-runoff-damage relationships in headwater creeks 6 sample watersheds ranging in size from 63 to 282 square miles were selected. These watersheds were considered representative of the problem areas in soil conservation in which they are located. Among the characteristics considered were topography, soils, land use, flood damages and type of flood plain. A flood series was developed for the 25-year period, 1920-1944. For this series, using rainfall-runoff relationships, depths of runoff were computed for the present conditions of the watershed and for future conditions which will prevail after installation of the recommended program. The reductions in runoff due to combinations of land treatment measures were determined from records obtained on experimental areas of similar cover and soil conditions. The methods used in computing the reduction in runoff in sample watersheds were also used for all creeks having records of stream flow measurements.

The relationship between surface runoff and peak discharge on ungaged areas was established from the examination of high water marks and by comparison with similar data on gaged streams. To obtain the average annual area inundated under present conditions the area inundated was computed by depth increments for each flood-producing storm of the series. Separate computations were then made to determine the areas inundated from each flood after installation of the recommended program.

The reductions in areas inundated resulting from installation of the recommended program in watersheds of creeks having stream gage records were computed in the following manner:

1. The damage-producing series of floods was determined from recorded flood flows.

2. The average depth of runoff from the contributing watershed was calculated for each damage-producing flood.

3. The reduced depths of runoff resulting from installation of the recommended program were then calculated.

4. Areas inundated were computed by the same method used for sample watersheds.

BASIC DATA

Precipitation Records

Precipitation records were obtained from "Climatological Data" published by the Weather Bureau, U. S. Department of Commerce. The stations and their periods of record are listed in figure 9 and their locations are shown in figure 10. The stations listed have at least 5 years of record prior to 1930 or one or more years during the period from 1930 through 1950.

Precipitation records from 19 stations were used in the preparation of figure 11, average annual rainfall. Average monthly precipitation, obtained from the same source, is shown for 18 locations within the watershed in table 15. Maximum and minimum precipitation for various periods and at selected stations are shown in table 16.

Stream Flow Records

Stream flow records used to establish the relationship between rainfall and runoff, and between surface runoff and probable peak discharge, were obtained from U. S. Geological Survey Water Supply Papers. The locations of stream gaging stations for which records are published are shown in figure 10. Information on location, period of operation and drainage area above the gages is shown in table 17. Stream discharge information for a number of stations is shown in table 18. Average annual runoff shown in the table was determined from data published in Water Supply Papers. Maximum flood discharges at various locations are shown in table 19.

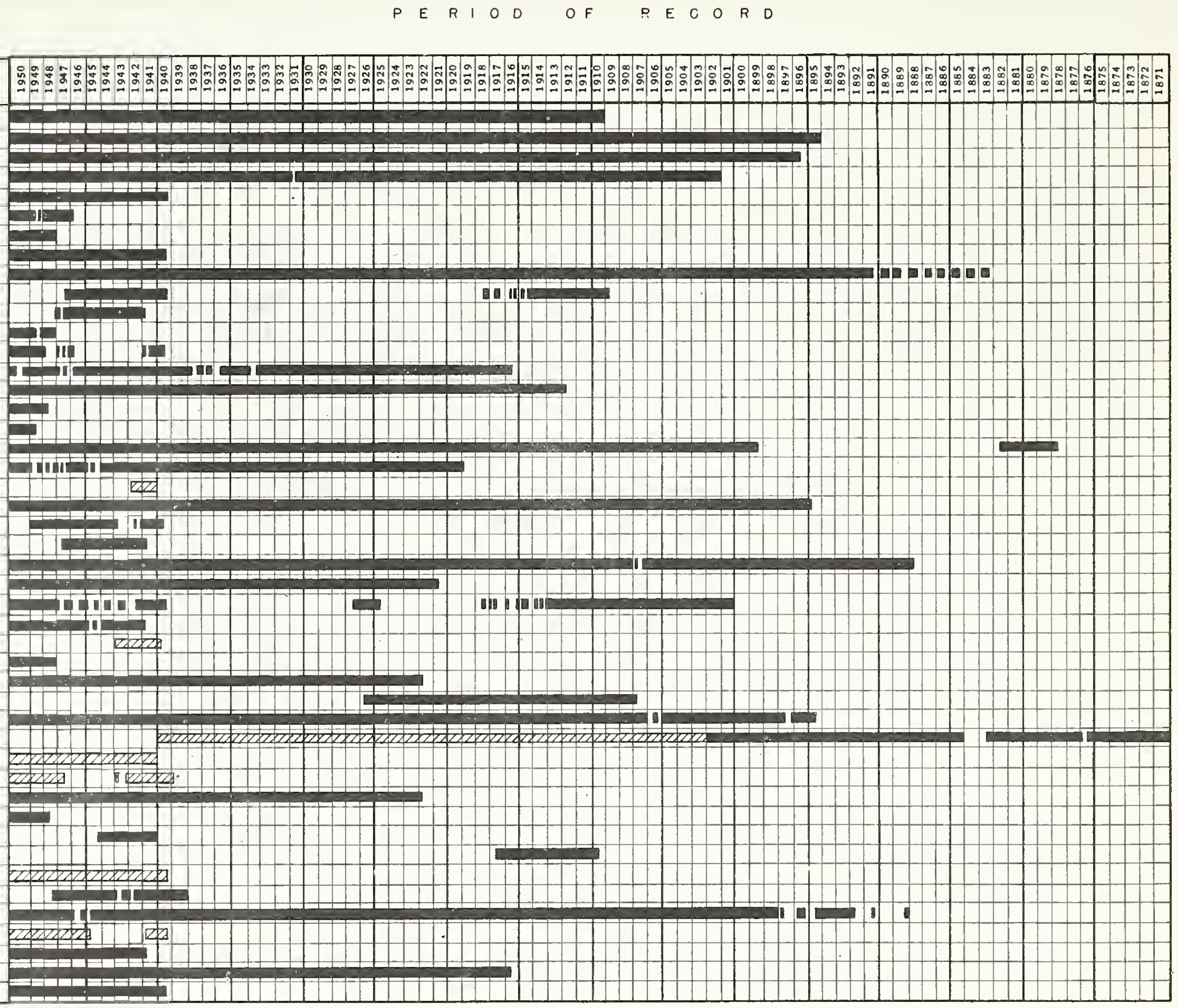
Flood Plain Data

Basic data for the determination of the relationship between rate of stream discharge and area flooded were obtained from engineering field surveys conducted in the valley areas of sample watersheds. These investigations included the use of aerial photographs, the field survey of valley and channel cross-sections and the determination of stream gradients. Seventy-five floodwater retarding structure sites were surveyed in sample watersheds. These sites are shown in figures 12 to 17. In addition, 31 structure sites were surveyed outside of sample watersheds, figure 18.

Infiltration and Runoff Data

The basic relationships between rainfall and runoff were determined from precipitation and stream gage records in creek watersheds. Data from the soil conservation experiment stations near Tyler and Temple, Texas, and the hydrologic watersheds near Waco and Garland, Texas, showing the quantitative effect of land use and treatment on rainfall-runoff relationships, were used to determine the reduction in runoff expected from the installation of land treatment measures on the sample watersheds.

No.	Station	Lat.	Long.	County
1	Austwell*	28°22'	96°50'	Refugio
2	Beeville	28°27'	97°42'	Bee
3	Blanco*	30°05'	98°25'	Blanco
4	Boerne	29°49'	98°45'	Kendall
5	Bulverde	29°45'	98°27'	Comal
6	Cibolo Creek	29°01'	97°56'	Karnes
7	Classen Ranch	29°39'	98°22'	Bexar
8	Crider Ranch	30°03'	99°47'	Real
9	Cuero*	29°04'	97°17'	DeWitt
10	Devine*	29°09'	98°54'	Medina
11	Divide School*	30° 07'	99°37'	Kerr
12	Fair Oaks Ranch	29°45'	98°38'	Comal
13	Falls City	28°57'	98°04'	Karnes
14	Floresville	29°08'	98°09'	Wilson
15	Goliad	28°40'	97°23'	Goliad
16	Goliad 6NE	28°43'	97°20'	Goliad
17	Goliad 1NE	28°38'	97°27'	Goliad
18	Hondo*	29°20'	99°09'	Medina
19	Karnes City	28°53'	97°54'	Karnes
20	Kelly Field	29°22'	98°35'	Bexar
21	Kerrville*	30°01'	99°07'	Kerr
22	La Vernia	29°22'	98°35'	Guadalupe
23	Lynxhaven Ranch*	29°58'	99°28'	Kerr
24	New Braunfels*	29°42'	98°06'	Comal
25	Nixon*	29°16'	97°46'	Gonzales
26	Port Lavaca*	28°37'	96°37'	Calhoun
27	Poteet*	29°03'	98°34'	Atascosa
28	Randolph Field	29°32'	98°17'	Bexar
29	Refugio	28°18'	97°17'	Refugio
30	Rio Medina	29°28'	98°52'	Medina
31	Rossville*	29°05'	98°41'	Atascosa
32	Runge	28°52'	98°43'	Karnes
33	San Antonio	29°26'	98°29'	Bexar
34	San Antonio Air Port	29°32'	98°28'	Bexar
35	San Antonio Nursery SCS	29°20'	98°29'	Bexar
36	Seguin	29°33'	97°58'	Guadalupe
37	Smithsons Valley	29°49'	98°20'	Comal
38	Stockdale	29°14'	97°58'	Wilson
39	Sutherland Springs	29°16'	98°04'	Wilson
40	Tarpley (Hydro)*	29°39'	99°16'	Bandera
41	Tarpley (NR)*	29°39'	99°17'	Bandera
42	Victoria*	28°47'	97°05'	Victoria
43	Victoria (Hydro)*	28°47'	97°01'	Victoria Hydro
44	Wilson, Adam Ranch*	29°54'	99°37'	Kerr
45	Woodsboro*	28°14'	97°20'	Refugio
46	Yorktown*	28°59'	97°30'	DeWitt



LEGEND

RECORDING GAGE

NON-RECORDING GAGE

* OUTSIDE WATERSHED

SOURCE: U. S. WEATHER BUREAU

Figure 9
PRECIPITATION STATIONS
SHOWING YEARS OF RECORD
SAN ANTONIO RIVER WATERSHED
TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL
REFERENCE

CARTOGRAPHIC APPROVAL TECHNICAL APPROVAL
G. L. Bilyeu Edmond H. Hajl
COMPILED TRACED CHECKED DATE
E.H.H. D.S. GGC 3/26/52

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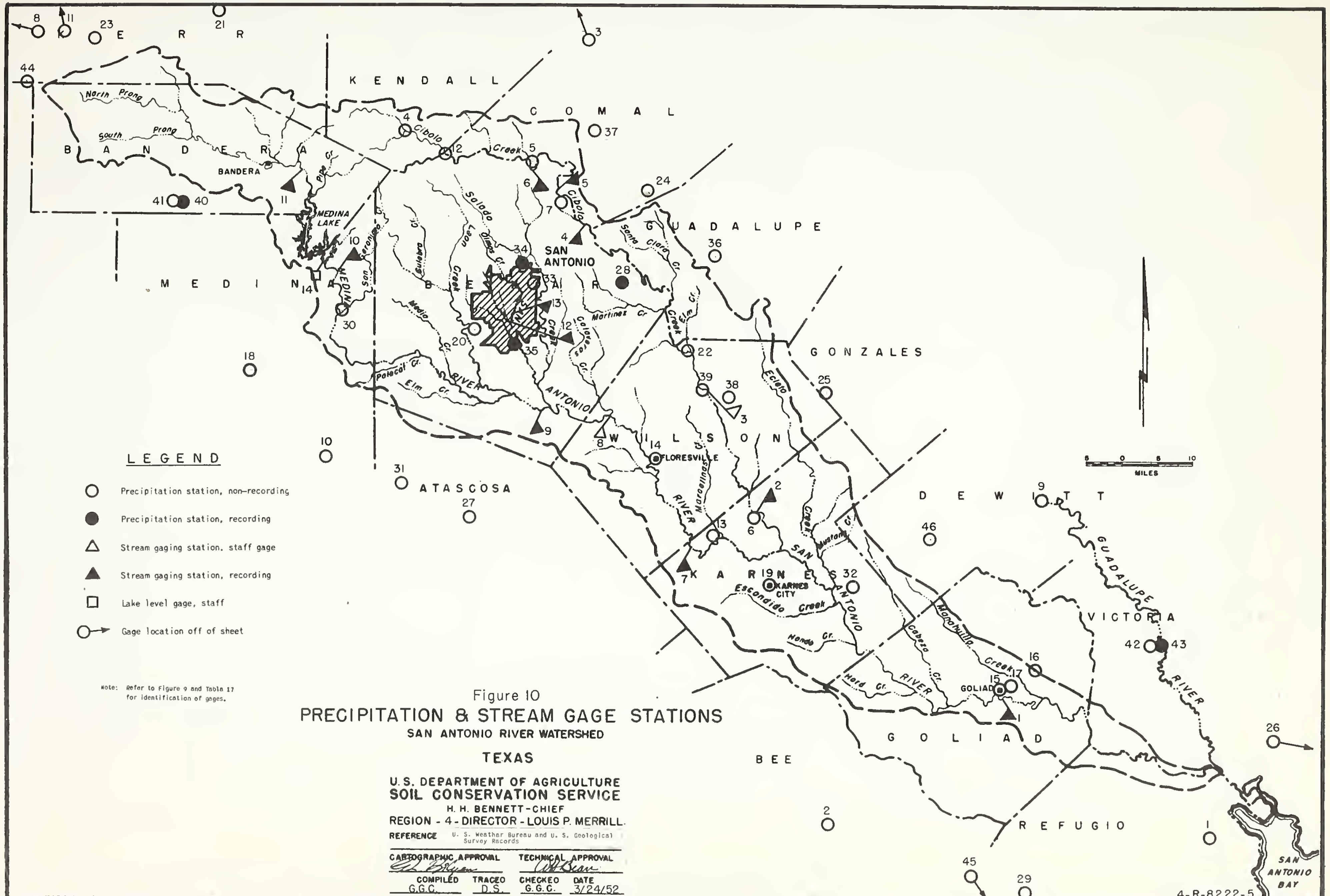


Figure 10

PRECIPITATION & STREAM GAGE STATIONS

SAN ANTONIO RIVER WATERSHED

TEXAS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT-CHIEF
REGION - 4 - DIRECTOR - LOUIS P. MERRILL
REFERENCE U. S. Weather Bureau and U. S. Geological Survey Records

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
COMPILED	TRACED	CHECKED	DATE
G.G.C.	D.S.	G.G.C.	3/24/52

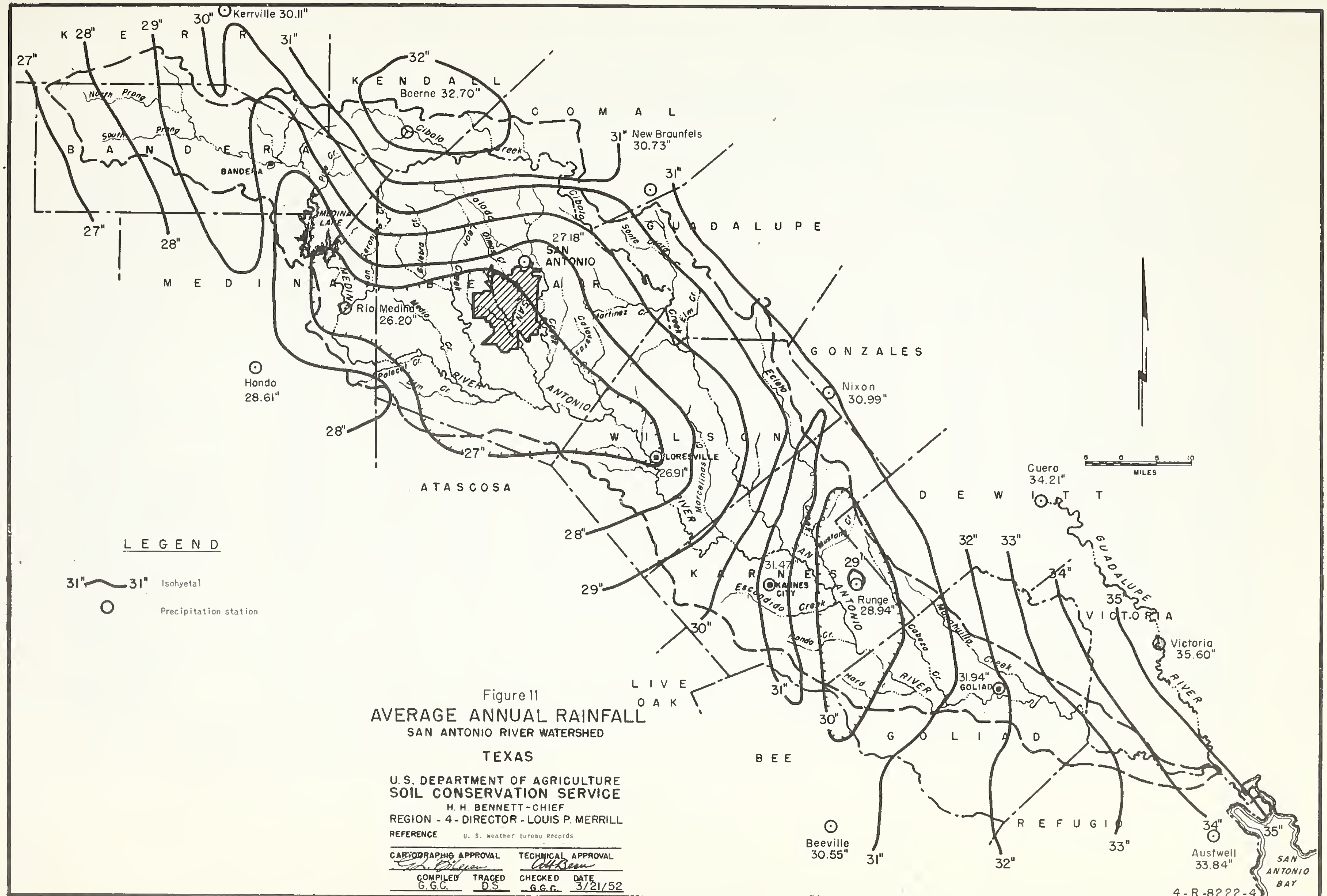


Figure 11
AVERAGE ANNUAL RAINFALL
SAN ANTONIO RIVER WATERSHED
TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT-CHIEF
REGION - 4 - DIRECTOR - LOUIS P. MERRILL
REFERENCE U. S. Weather Bureau Records

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
COMPILED	TRACED	CHECKED	DATE
G.G.C.	D.S.	G.G.C.	3/21/52

Table 15. Average Monthly Precipitation at Various Stations 1/

San Antonio River Watershed, Texas

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Austwell	2.12	1.75	1.95	2.46	3.47	3.12	3.19	2.35	4.55	3.60	2.07	3.21
Beeville	1.70	1.71	2.23	2.14	3.72	3.12	3.05	2.30	3.56	2.42	2.22	2.38
Blanco	1.76	1.86	1.99	3.52	3.65	2.37	2.93	1.97	3.11	3.04	2.25	2.37
Boerne	1.84	2.08	1.98	3.51	4.29	2.68	2.87	2.21	3.60	3.15	2.21	2.28
Cuero	2.16	2.24	2.33	2.78	3.97	3.73	2.94	2.19	3.24	2.95	2.86	2.82
Floresville	1.79	1.74	1.78	2.44	3.28	3.07	2.23	1.61	2.96	2.24	1.78	1.99
Goliad	2.19	1.73	2.26	2.15	3.62	3.01	3.15	2.41	3.54	2.80	2.43	2.65
Hondo	1.47	1.58	1.87	3.17	4.40	2.71	2.58	1.90	3.08	2.39	1.68	1.78
Karnes City	2.26	1.68	2.32	2.33	4.01	3.33	2.64	1.96	3.65	2.52	2.14	2.63
Kerrville	1.44	1.60	1.85	3.10	3.91	2.99	2.58	2.04	3.59	2.79	2.15	2.07
New Braunfels	1.95	1.91	2.16	3.30	3.84	3.02	2.33	1.88	2.93	3.02	2.05	2.34
Nixon	2.17	1.69	2.45	3.01	3.44	2.95	2.79	1.79	3.40	2.68	2.02	2.60
Port Lavaca	1.15	2.44	2.01	2.66	3.70	2.48	4.23	3.16	4.72	4.90	2.70	2.95
Riomedina	1.49	1.83	1.91	2.64	3.46	3.28	2.60	1.57	2.60	1.87	1.10	1.85
Runge	1.58	1.91	1.93	2.74	3.70	2.93	2.68	1.75	3.00	2.33	2.03	2.36
San Antonio	1.46	1.65	1.84	3.19	3.20	2.46	2.17	2.42	3.05	2.23	1.90	1.61
Victoria	2.43	2.12	2.33	2.74	4.13	3.25	3.67	2.77	3.67	3.15	2.57	2.77
Woodsboro	1.99	1.52	2.22	2.64	3.44	3.09	3.29	2.56	4.53	2.35	1.87	2.78

1/ U. S. Weather Bureau Records.

Table 16. Maximum and Minimum Precipitation at Selected Stations

San Antonio River Watershed, Texas

Station	Years of Complete Record 1/	Maximum 24-hour		Maximum Monthly		Minimum 3-month		Minimum Annual	
		Date	Inches	Date	Inches	Beginning Date	Inches	Date	Inches
Austwell 2/	42	7-22-19	11.40	June 1921	22.06	Jan. 1916	0.70	1917	14.27
Beeville 2/	55	9-15-19	8.20	July 1903	16.42	Oct. 1950	0.19	1917	12.09
Boerne	60	10-2-13	9.04	Oct. 1913	16.37	Jan. 1925	0.54	1893	16.96
Bulverde	10	9-27-46	6.32	Sept. 1946	12.96	Oct. 1950	0.69	1948	19.34
Floresville	29	6-13-35	8.35	July 1942	11.43	Mar. 1938	0.28	1918	7.88
Goliad	38	7-6-42	7.06	July 1942	13.14	Jan. 1916	0.53	1917	9.73
Hondo 2/	74	5-31-35	9.15	May 1935	22.40	Oct. 1950	0.53	1917	14.45
Karnes City	31	6-10-35	9.75	June 1935	13.47	Oct. 1950	0.69	1939	17.08
Kerrville 2/	55	7-15-00	11.60	Sept. 1936	19.94	Jan. 1925	0.36	1917	12.33
New Braunfels 2/	62	9-8&9-21	9.41	Oct. 1919	16.44	Jan. 1925	0.34	1893	15.42
Runge	53	6-27-31	7.52	July 1903	13.91	Oct. 1950	0.35	1917	13.60
San Antonio	77	10-1&2-13	7.08	Sept. 1859	17.60	Feb. 1925	0.51	1917	10.11

1/ Through December 31, 1950.

2/ Outside of Watershed.

Table 17. Stream and Lake Level Gages

San Antonio River Watershed, Texas

Code No. 1/	Name and Location	Drainage Area 2/ (sq. mi.)	Period of Operation (years)	Years of Operation 3/ (yrs.mo.)
1	San Antonio River at Goliad	3,897	1924-1929 1939-1949	15-4
2	Cibolo Creek near Falls City	837	1930-1949	18-11
3	Cibolo Creek at Sutherland Springs	656	1924-1929	4-10
4	Cibolo Creek at Selma	282	1946-1949	3-7
5	Cibolo Creek above Braken	259	1946-1949	3-2
6	Cibolo Creek above Bulverde	205	1946-1949	3-6
7	San Antonio River near Falls City	2,106	1925-1949	24-6
8	San Antonio at Calaveras	1,864	1918-1925	7-5
9	Medina River near San Antonio	1,305	1939-1949	10-2
10	Medina River near Riomedina	648	1914-1916 1918-1934	18-0
11	Medina River near Pipe Creek	470	1922-1934	11-10
12	San Pedro Creek at San Antonio	2	1916-1929	13-4
13	San Antonio River at San Antonio	41	1915-1929 1939-1949	25-6
14	Medina Lake near San Antonio 4/	587	1913-1949	36-5

1/ Refers to numbers on figure 10.
2/ From U. S. Army, Corps of Engineers.
3/ Years for which daily discharge records are available.
4/ Lake level gage. Monthly changes in volume.

Table 18. Annual Runoff and Maximum and Minimum Discharges at Various Locations 1/

San Antonio River Watershed, Texas

Code No. 2/	Name and Location	Average Discharge (U.S.G.S. Averages) (second-feet)	Average 3/ Annual Runoff (inches)	Average 3/ Annual Runoff (acre-feet)	Maximum Peak Discharge (second-feet)	Minimum Discharge (second-feet)
1	San Antonio River at Goliad	586	1.95	405,610	33,800	44
2	Cibolo Creek near Falls City	129	2.03	90,719	33,600	4
3	Cibolo Creek at Southerland Springs	Not determined	1.29	45,214	23,800	4.4
4	Cibolo Creek at Selma	Not determined	0.25	3,829	7,240	0
5	Cibolo Creek above Braken	Not determined	0.07	903	11.04 5/	0
6	Cibolo Creek above Bulverde	Not determined	0.39	4,253	12.5 5/	0
7	San Antonio River near Falls City	330	2.09	234,505	47,400	36
8	San Antonio River at Calaveras	Not determined	2.515	250,056	42.0 5/	15
9	Medina River near San Antonio	124	1.27	88,420	31,800	5.9
10	Medina River near Riomedina	Not determined	0.688 4/	23,777	11,800	0
11	Medina River near Pipe Creek	103	2.89	72,458	64,800	2.2
12	San Pedro Creek at San Antonio	Not determined	55.09	5,876	8.6 5/	0
13	San Antonio River at San Antonio	69.5	23.36	51,086	15,300	0

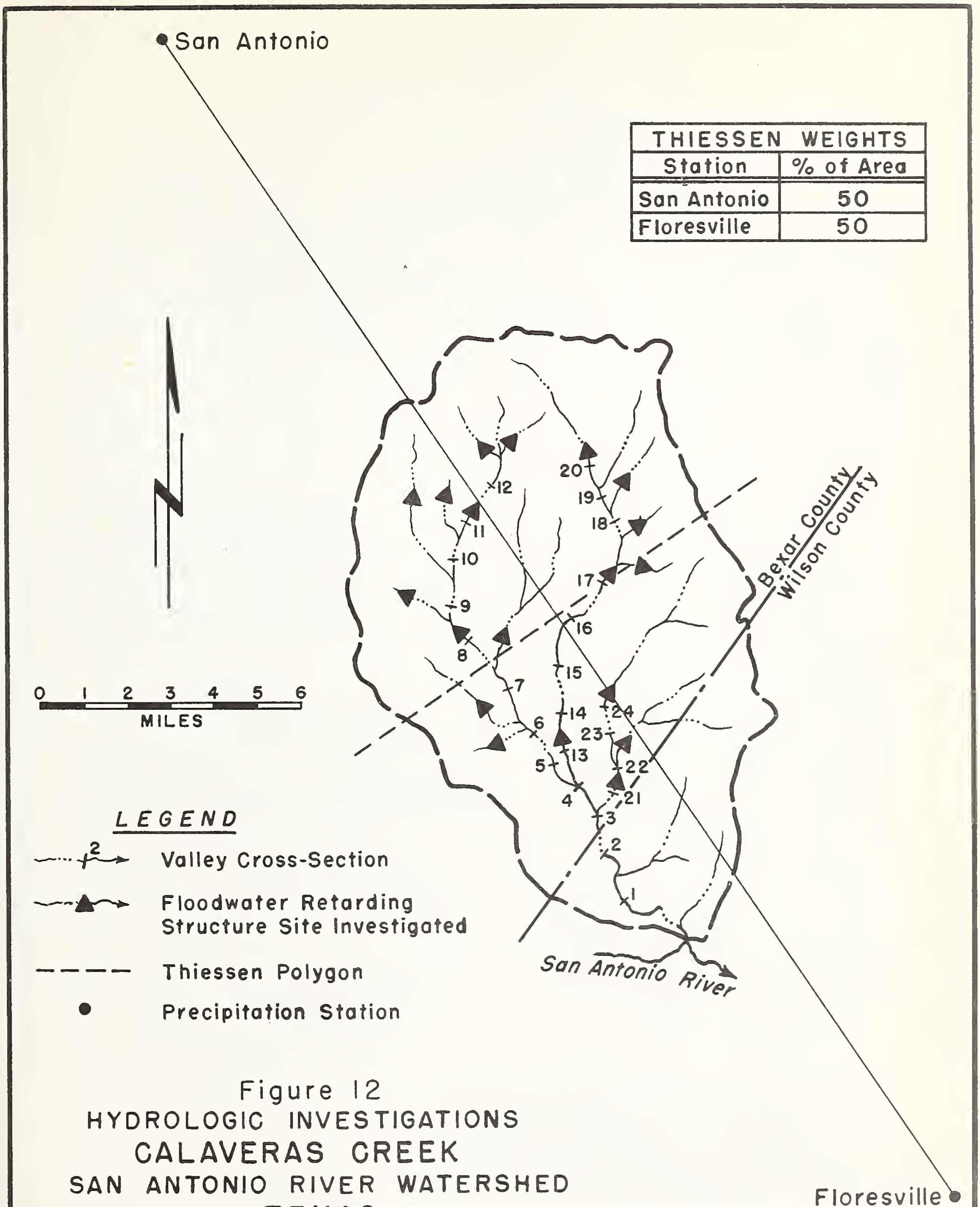
1/ As of September 30, 1949.
2/ Refers to numbers shown on location map, figure 10. Source of data: U. S. Geological Survey, Water Supply Papers.
3/ Computed from daily records.
4/ From U. S. Army, Corps of Engineers.
5/ Gage reading, discharge not available.

Table 19. Miscellaneous Maximum Flood Discharges

San Antonio River Watershed, Texas

Code No.	Stream	Station	Date	Drainage Area (square miles)	Discharge in C.F.S. 1/	Discharge (c.f.s. per square mile)
12	San Pedro Creek	San Antonio	9-9-21	2.0	2,020	1,010
-	Martinez Creek	San Antonio 2/	9-27-46	6.3 3/	3,950	627
-	Frederick Creek	Boerne 2/	6-1-37	16.1 3/	16,300	1,012
-	Alazan Creek	San Antonio 2/	9-9-21	17.1 3/	25,900	1,515
-	Alazan Creek	San Antonio 2/	9-9-21	18.7 3/	28,000	1,497
-	Apache Creek	San Antonio 2/	9-10-21	23.8 3/	22,600	950
-	Calaveras Creek	Elmendorf 2/	9-27-46	24.6 3/	58,000	2,358
-	Olmos Creek	San Antonio 2/	9-9-21	26.4 3/	28,000	1,061
13	San Antonio River	San Antonio	9-10-21	41.0	15,300	373
-	San Pedro Creek	San Antonio 2/	9-9-21	46.5	32,400	697
-	North Fork of Medina River	Lima 2/	7-1-32	54.0 3/	40,200	744
-	Escondido Creek	Kenedy 2/	8-29-46	80	28,000 4/	350
-	San Antonio River	San Antonio 2/	9-10-21	85 3/	42,400	499
-	Cibolo Creek	Van Raub 2/	6-1-37	115 3/	58,900	512
-	Salado Creek	San Antonio 2/	9-27-46	161 3/	50,000	311
-	Medina River	Medina 2/	7-1-32	235 3/	47,600	203
11	Medina River	Pipe Creek	1919	470	97,500 4/	207
10	Medina River	Riomedina	9-16-19	648	17,900 5/	28
3	Cibolo Creek	Sutherland Springs	4-21-26	656	23,800	36
2	Cibolo Creek	Falls City	Oct.1913	837	34,800 4/	42
9	Medina River	San Antonio	8-29-46	1,305	31,800	24
7	San Antonio River	Falls City	9-29-46	2,106	47,400	23

1/ U.S.G.S., Water Supply Papers. 2/ Miscellaneous measurement -- not at regular U.S.G.S. gaging station. 3/ Drainage Area determined by U.S.G.S. 4/ Estimated by U. S. Army, Corps of Engineers. 5/ Average daily discharge.



THIESSEN WEIGHTS	
Station	% of Area
San Antonio	50
Floresville	50

Figure 12
HYDROLOGIC INVESTIGATIONS
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL
REFERENCE

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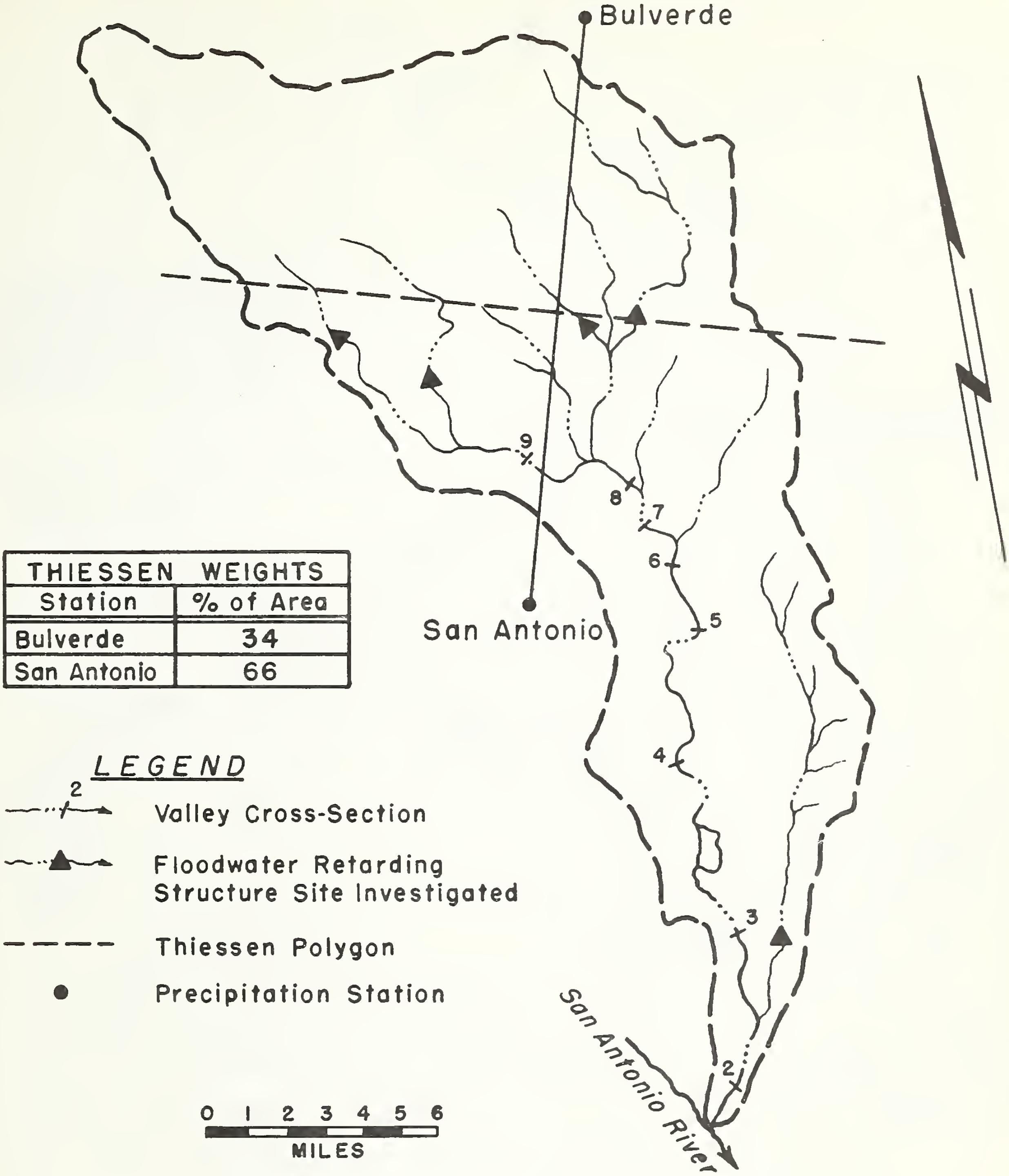

THIESSEN WEIGHTS	
Station	% of Area
Bulverde	34
San Antonio	66

Figure 13
HYDROLOGIC INVESTIGATIONS
SALADO CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

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COMPILED	TRACED	CHECKED	DATE
G.G.C.	J.W.M.	G.G.C.	3-27-52

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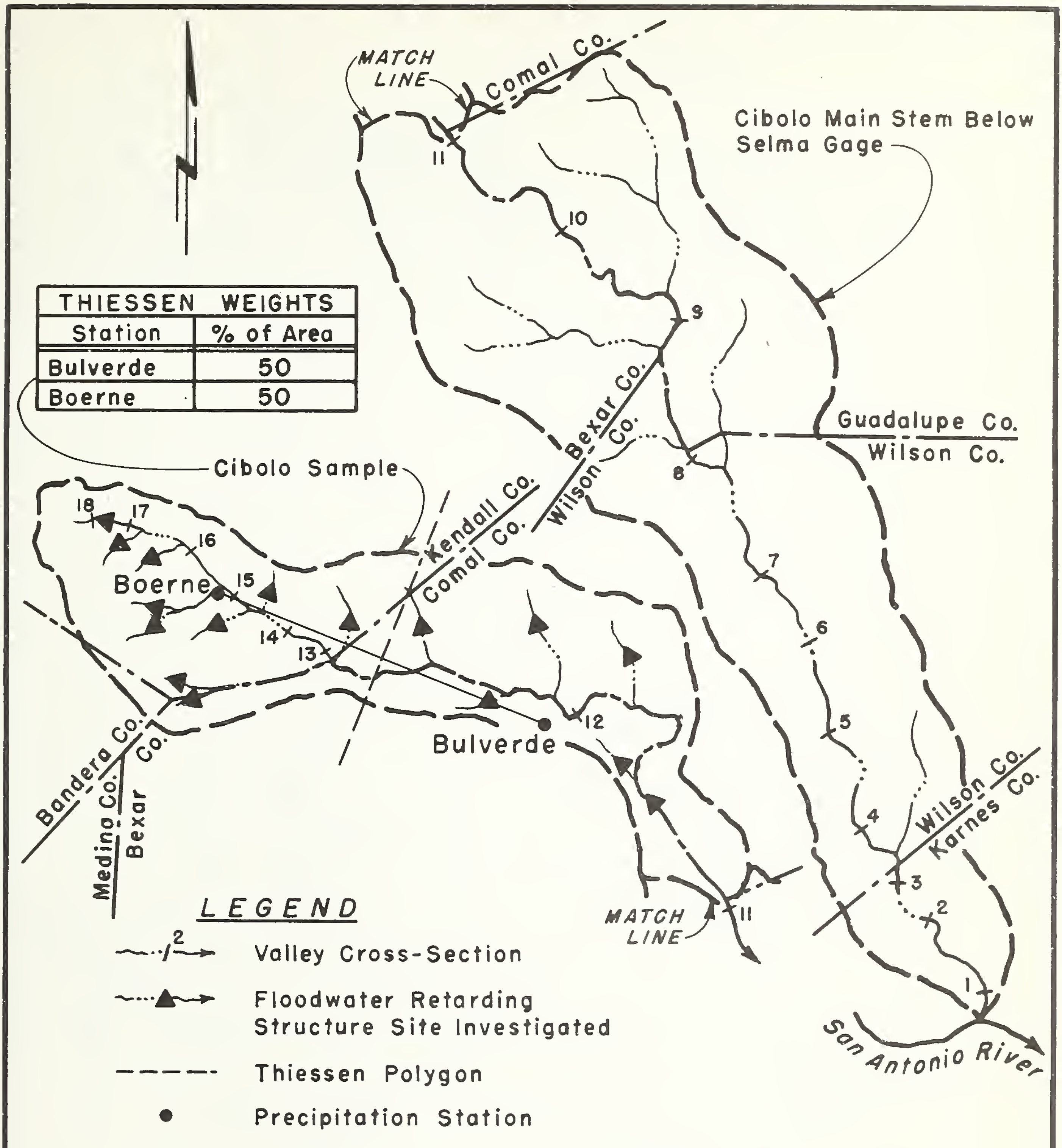

Figure 14
HYDROLOGIC INVESTIGATIONS
CIBOLO CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

0 1 2 3 4 5 6 7
MILES

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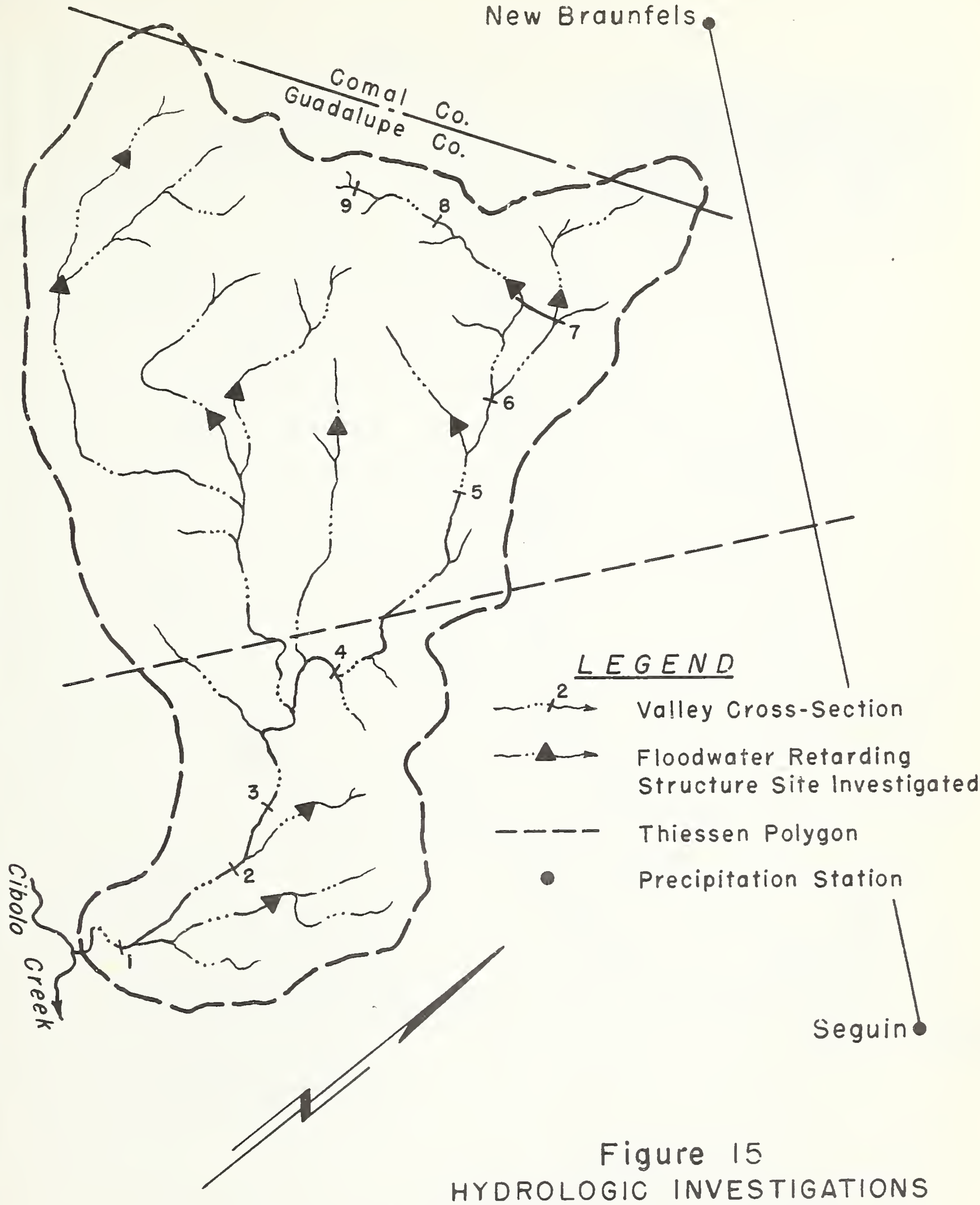

Figure 15
HYDROLOGIC INVESTIGATIONS
SANTA CLARA CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

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THIESSEN WEIGHTS	
Station	% of Area
Seguin	34
New Braunfels	66

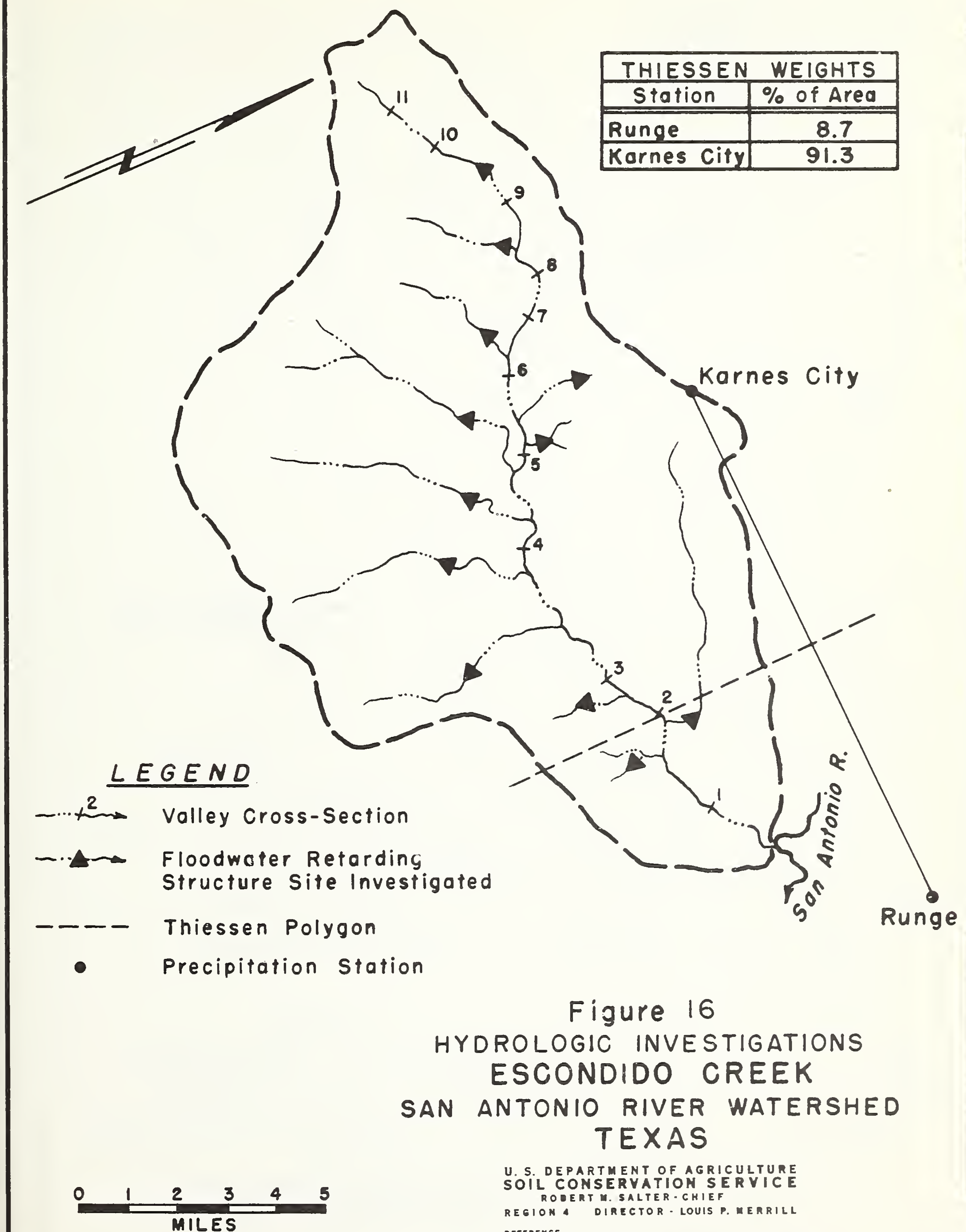

Figure 16
HYDROLOGIC INVESTIGATIONS
ESCONDIDO CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

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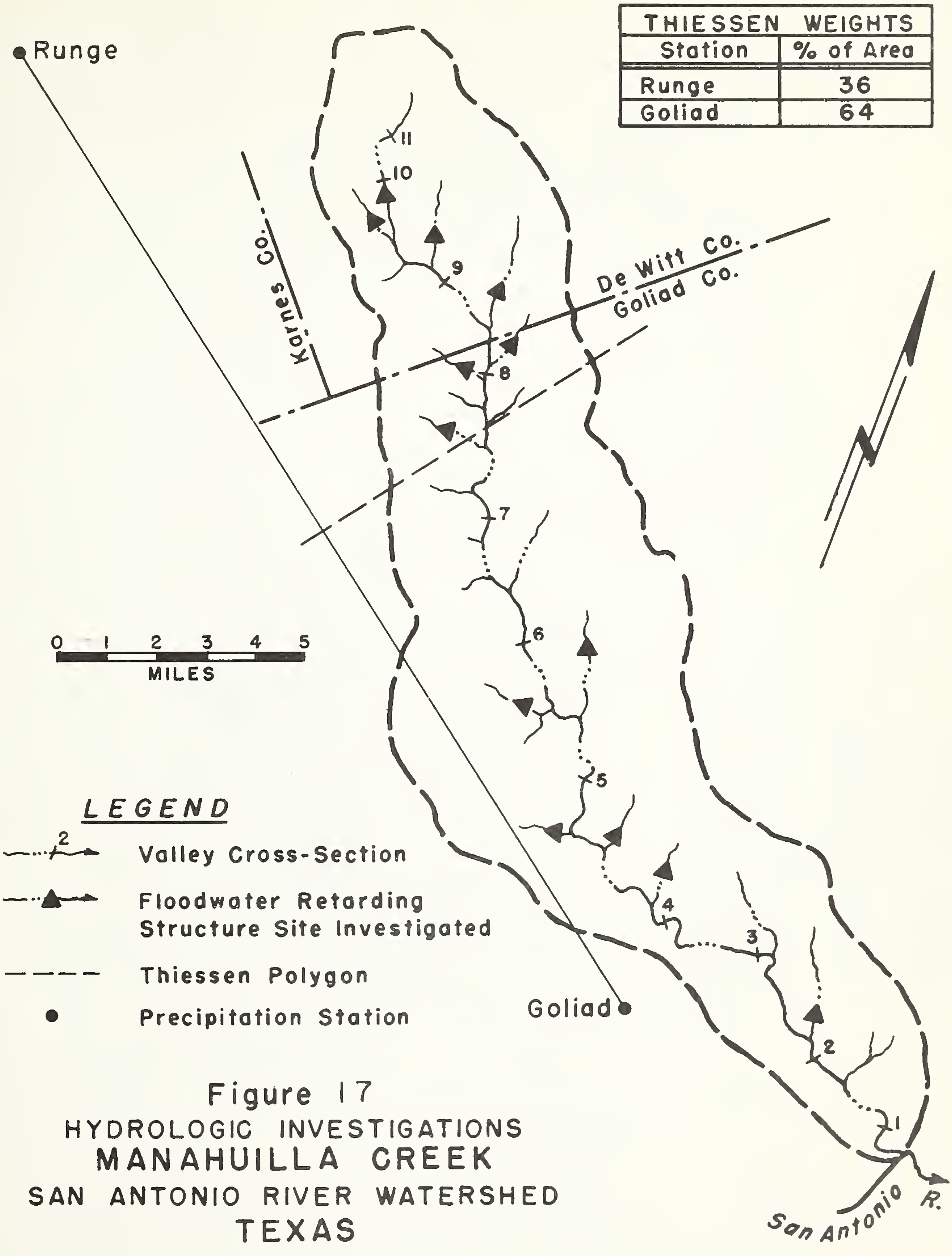

Figure 17
HYDROLOGIC INVESTIGATIONS
MANAHUILLA CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

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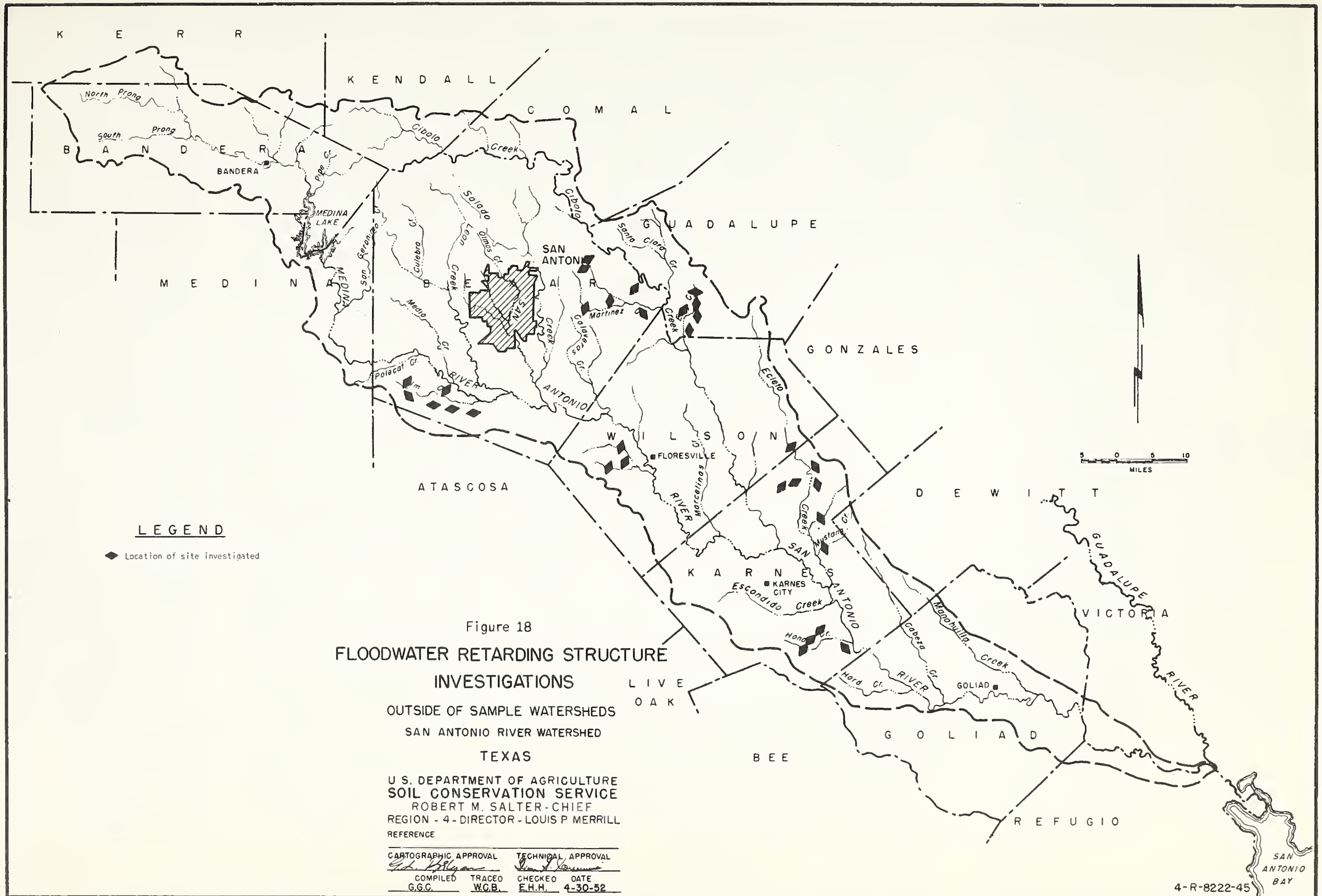

Figure 18

FLOODWATER RETARDING STRUCTURE INVESTIGATIONS

OUTSIDE OF SAMPLE WATERSHEDS

SAN ANTONIO RIVER WATERSHED

TEXAS

D S 9/5/51 4-R-8222

CALCULATION OF FLOOD REDUCTIONS

Rainfall-Runoff Relationship

The Thiessen polygon weighting method was used to determine the rainfall on the contributing area above a stream gage. The volume of runoff resulting from the storm being studied was calculated from the hydrograph of the stream discharge. The depths of runoff in inches from selected typical storms were plotted opposite the depth of precipitation causing the runoff and a curve was drawn to represent an average of the plotted points.

In developing curves indicating rainfall-runoff relationships for tributaries for which stream discharge records were not available, runoff factors were determined for each soil and cover complex represented in a similar gaged tributary watershed. The runoff factors were determined by an analysis of applicable experimental data. These runoff factors indicate the relative runoff to be expected, for various amounts of rainfall, from each soil-cover complex, table 20. For convenience, a factor value of unity was assigned to the runoff expected from a "cultivated, untreated, deep or shallow, fine textured" soil-cover complex. The inches of runoff to be expected from each other soil-cover complex for each rainfall amount (in inches) considered was determined by multiplying the expected inches of runoff from the "unity" soil-cover complex by the runoff factor of each other soil-cover complex. The result was multiplied by the area of the soil-cover complex in acres to determine the total volume of runoff in acre-inches from each soil-cover complex for each amount of rainfall. Figure 19 shows the rainfall-runoff curve for Pecan Bayou, Colorado River Watershed, which was developed by plotting various amounts of precipitation against the corresponding expected inches of runoff as computed in table 20.

Table 21 shows the rainfall-runoff relationships for present conditions for the Calaveras Creek Watershed, using the runoff values as computed in table 20 for the various soil-cover complexes and amounts of rainfall. The total volume of runoff for each depth of rainfall was obtained by multiplying the area of each soil-cover complex in acres by the depth of runoff in inches from that area. The total number of acre-inches divided by the total area in acres gave the weighted average depth of runoff in inches for Calaveras Creek. By plotting amounts of rainfall against corresponding runoff in inches the curve of rainfall-runoff relationships for present conditions on the Calaveras Creek Watershed, shown in figure 20, was obtained.

Table 22 shows the rainfall-runoff relationships after application of complete land treatment and stabilization measures on the Calaveras Creek Watershed. The rainfall-runoff relationships for each soil-cover complex, as shown in table 22, are the same as for present conditions, but the application of land treatment and stabilization measures on the

Table 20. Soil Cover Complex Data Sheet for Computing Rainfall-Runoff Relationship in Pecan Bayou, Colorado River, Texas

San Antonio River Watershed, Texas

Present Condition — Above Brownwood Gaging Station

Soil-Cover Complex	Acres	P = 1" Factor	P = 1" Y	P = 2" Factor	P = 2" Y	P = 4" Factor	P = 4" Y	P = 6" Factor	P = 6" Y	P = 8" Factor	P = 8" Y	P = 10" Factor	P = 10" Y
Cultivated Untreated - D&S - FT	117,344	1.000	.0484	1.000	.3561	1.000	1.0463	1.000	1.8779	1.000	2.8419	1.000	3.9508
Cultivated Untreated - D&S - MT	46,329	.750	.036	.814	.290	.871	.911	.902	1.694	.920	2.615	.932	3.682
Cultivated Untreated - D&S - CT	10,306	.645	.031	.751	.267	.831	.869	.870	1.634	.895	2.544	.911	3.599
Cultivated Untreated - VS - FT	810	1.000	.048	1.000	.356	1.000	1.046	1.000	1.878	1.003	2.850	1.020	4.030
Cultivated Untreated - VS - MT	300	.750	.036	.814	.290	.909	.951	.977	1.835	1.003	2.850	1.020	4.030
Cultivated Untreated - VS - CT	50	.645	.031	.751	.267	.909	.951	.977	1.835	1.003	2.850	1.020	4.030
Cultivated Treated - D&S - FT	87,133	.502	.024	.686	.244	.790	.827	.837	1.572	.865	2.458	.885	3.496
Cultivated Treated - D&S - MT	36,703	.375	.018	.581	.207	.725	.759	.788	1.480	.825	2.345	.850	3.358
Cultivated Treated - D&S - CT	11,637	.285	.014	.518	.184	.680	.711	.754	1.416	.800	2.274	.830	3.279
Pasture - Excellent - D&S	28,332	.004	-	.213	.076	.467	.489	.579	1.087	.645	1.833	.694	2.742
Pasture - Good - D&S	189,443	.015	.001	.301	.107	.515	.539	.617	1.159	.683	1.941	.727	2.872
Pasture - Fair - D&S	296,163	.239	.012	.470	.167	.631	.660	.720	1.352	.772	2.194	.806	3.184
Pasture - Poor - D&S	85,656	.797	.039	.841	.299	.890	.931	.918	1.724	.936	2.660	.947	3.741
Pasture - Fair - VS	59,085	.239	.012	.470	.167	.758	.793	.879	1.651	.931	2.646	.964	3.809
Pasture - Poor - VS	39,565	.797	.039	.841	.299	.890	.931	.918	1.724	.967	2.748	.992	3.919
Pasture - Fair - RB	10,385	.239	.012	.669	.238	.909	.951	.977	1.835	1.003	2.850	1.020	4.030
Pasture - Poor - RB	8,642	.797	.039	.841	.299	.985	1.031	1.025	1.925	1.039	2.953	1.049	4.144
Woods - Good - D&S	-	.004	-	.213	.076	.467	.488	.579	1.087	.645	1.833	.694	2.742
Woods - Fair - D&S	-	.059	.003	.375	.134	.565	.591	.658	1.236	.719	2.043	.760	3.003
Woods - Poor - D&S	-	.547	.026	.700	.249	.800	.837	.845	1.587	.873	2.481	.892	3.524
Woods - Good - VS&RB	-	.004	-	.213	.076	.524	.548	.729	1.369	.821	2.333	.876	3.461
Woods - Fair - VS&RB	-	.059	.003	.375	.134	.679	.710	.828	1.555	.894	2.541	.934	3.690
Woods - Poor - VS&RB	-	.547	.026	.700	.249	.800	.837	.879	1.651	.931	2.646	.964	3.809
Miscellaneous - Roads, Urban, etc.	10,197	1.094	.053	1.138	.405	1.121	1.173	1.113	2.090	1.103	3.135	1.100	4.346
Total Acres and Acre-Inches	1,038,080		20,762		217,997		788,941		1,546,739		2,460,250		3,529,472
Weighted Average Inches Runoff			.020		.21		.76		1.49		2.37		3.40

Explanation of terms used

D - Deep
S - Shallow
VS - Very shallow
RB - Rough broken
FT - Fine textured

MT - Medium textured
CT - Coarse textured
P - Precipitation
Y - Runoff, inches

Pasture

Excellent - 100% perennial cover.
Good - 75% perennial cover - good litter.
Fair 50% to 75% perennial cover - fair litter.
Poor - Less than 50% perennial cover - no litter.

Woods

Good - Neither burned or grazed.
Fair - Burned or grazed.
Poor - Burned and grazed.

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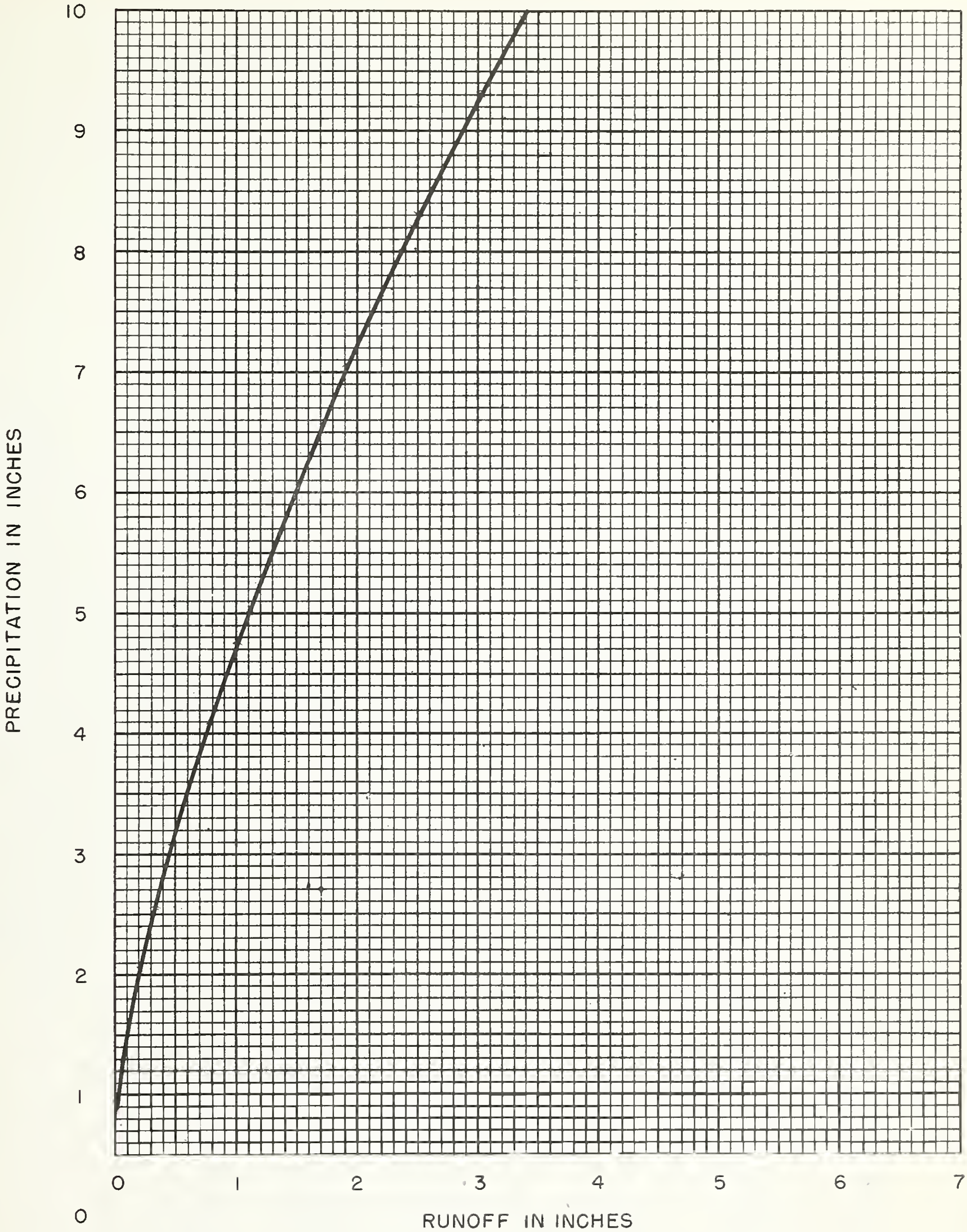

Figure 19

RAINFALL - RUNOFF RELATIONSHIP
FOR PECAN BAYOU
NEAR BROWNWOOD,TEXAS

SAN ANTONIO RIVER WATERSHED
TEXAS

4/28/52 4-N-8222-44

Table 21. Rainfall-Runoff Relationships
Calaveras Creek, Bexar and Wilson Counties

San Antonio River Watershed, Texas

Soil-Cover Complex	Acres	Present Conditions P = 1" Runoff (inches)	P = 2" Runoff (inches)	P = 4" Runoff (inches)	P = 6" Runoff (inches)	P = 8" Runoff (inches)	P = 10" Runoff (inches)
Cultivated Untreated - D&S - FT	4,509	.048	.356	1.05	1.88	2.84	3.95
Cultivated Untreated - D&S - MT	11,488	.036	.290	.91	1.70	2.61	3.68
Cultivated Untreated - D&S - CT	1,855	.031	.267	.87	1.64	2.54	3.60
Cultivated Treated - D&S - FT	1,272	.024	.244	.83	1.57	2.46	3.50
Cultivated Treated - D&S - MT	3,240	.018	.207	.76	1.48	2.34	3.36
Cultivated Treated - D&S - CT	523	.014	.184	.71	1.42	2.27	3.28
Pasture - Good - D&S	2,260	-	.107	.54	1.16	1.94	2.87
Pasture - Fair - D&S	7,350	.011	.167	.66	1.35	2.19	3.18
Pasture - Poor - D&S	27,685	.038	.299	.93	1.73	2.66	3.74
Pasture - Poor - VS	48	.038	.299	.93	1.73	2.75	3.92
Miscellaneous - Roads, Urban, etc.	1,210	.052	.405	1.18	2.09	3.13	4.34
Total Acres and Acre - Inches	61,440	1,981	16,761	53,983	101,635	157,441	222,659
Weighted Average Inches Runoff		.032	.273	.88	1.65	2.56	3.62

Explanation of terms used

D - Deep
S - Shallow
VS- Very Shallow
FT- Fine Textured

MT - Medium textured
CT - Coarse textured
P - Precipitation

Pasture

Excellent - 100% perennial cover.
Good - 75% perennial cover - good litter.
Fair - 50% to 75% perennial cover - fair litter.
Poor - Less than 50% perennial cover - no litter.

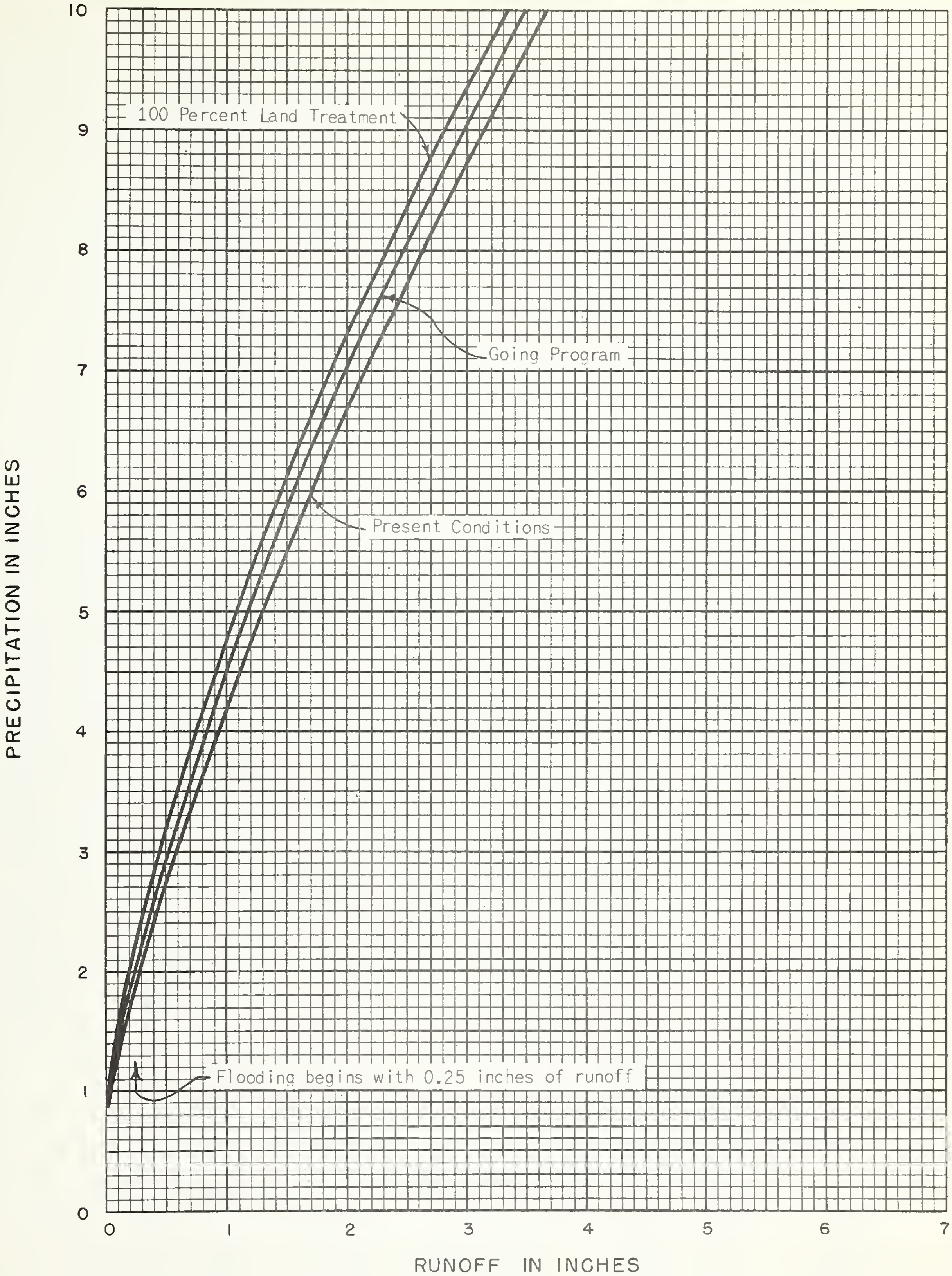

Figure 20
RAINFALL - RUNOFF RELATIONSHIP FOR CALAVERAS CREEK
BEXAR AND WILSON COUNTIES
SAN ANTONIO RIVER WATERSHED
TEXAS

3/27/52 4-R-8222-16

Table 22. Rainfall-Runoff Relationships
Calaveras Creek, Bexar and Wilson Counties

San Antonio River Watershed, Texas

Soil-Cover Complex	Acres	Recommended Land Treatment in Effect: P = 1" Runoff (inches)	P = 2" Runoff (inches)	P = 4" Runoff (inches)	P = 6" Runoff (inches)	P = 8" Runoff (inches)	P = 10" Runoff (inches)
Cultivated Treated - D&S - FT	5,614	.024	.244	.83	1.57	2.46	3.50
Cultivated Treated - D&S - MT	14,301	.018	.207	.76	1.48	2.34	3.36
Cultivated Treated - D&S - CT	2,309	.014	.184	.71	1.42	2.27	3.28
Pasture - Good - D&S	9,617	-	.107	.54	1.16	1.94	2.87
Pasture - Fair - D&S	16,374	.011	.167	.66	1.35	2.19	3.18
Pasture - Poor - D&S	11,967	.038	.299	.93	1.73	2.66	3.74
Pasture - Fair - VS	24	.012	.167	.79	1.65	2.65	3.81
Pasture - Poor - VS	24	.038	.299	.93	1.73	2.75	3.92
Miscellaneous - Roads, Urban, etc.	1,210	.052	.405	1.18	2.09	3.13	4.34
Total Acres and Acre-Inches	61,440	1,123	12,598	45,766	89,832	142,781	205,137
Weighted Average Inches Runoff		.0183	.205	.745	1.46	2.32	3.34

Explanation of terms used

D - Deep
S - Shallow
VS - Very shallow
FT - Fine textured
MT - Medium textured
CT - Coarse textured
P - Precipitation

Pasture

Excellent - 100% perennial cover.
Good - 75% perennial cover - good litter.
Fair - 50% to 75% perennial cover - fair litter.
Poor - Less than 50% perennial cover - no litter.

Calaveras Creek Watershed changed the acreages of the various soil-cover complexes and decreased the expected runoff for each given amount of rainfall. The 100 percent land treatment curve in figure 20 was plotted from the data in table 22.

The middle curve in figure 20 shows the rainfall-runoff relationship for the "going" program. The same procedure as described above was used in determining this relationship. This curve represents the effect of the application of land treatment measures which are being applied in the Calaveras Creek Watershed by current agricultural programs. The amounts of these measures applied during the installation period of the recommended program are considered as being the "going" program. Figure 21 shows the rainfall-runoff relationships for present conditions on the other sample watersheds investigated.

Runoff-Peak Discharge Relationship

The runoff-peak discharge relationship in a given watershed is influenced by many factors including area, topography, climate, soils, land use and the shape, density, orientation, and hydraulics of the stream channels. The ratio of the depth of runoff to the corresponding peak rate of discharge under average conditions is constant for a given watershed, as shown in figure 22. A volume or depth of 1.00 inch of runoff on this curve indicates a peak discharge of 9,800 c.f.s., and a runoff of 2.00 inches can be expected to produce 19,600 c.f.s. The runoff-peak discharge relationships for the remaining 5 sample watersheds are shown in figure 23.

Runoff-peak discharge curves were developed for the gaged areas in the San Antonio River Watershed which are not materially affected by storage reservoirs or diversions. These curves were compared with and checked by curves developed from gaged areas near the San Antonio River Watershed, as well as by the relationship of discharge in c.s.m. for 1.00 inch of runoff at various gaged stations.

Peak discharges on sample watersheds were computed from high water marks or miscellaneous discharge measurements where available, and were related to precipitation amounts and volumes or depths of runoff which produced these peaks. These peak discharges were compared to stream gage data for similar conditions and adjusted so that reasonable runoff-peak discharge relationships could be established for use in further computations.

The relationship between depth of runoff and the peak rate of discharge in second feet at valley cross-section number 1 on Calaveras Creek is shown in figure 22. This relationship was based on high water marks for the flood of September 1946 and substantiated by a miscellaneous discharge measurement by the Corps of Engineers.

The momentary peak discharges which produced the flood high water marks at all the valley cross-sections on Calaveras Creek were determined

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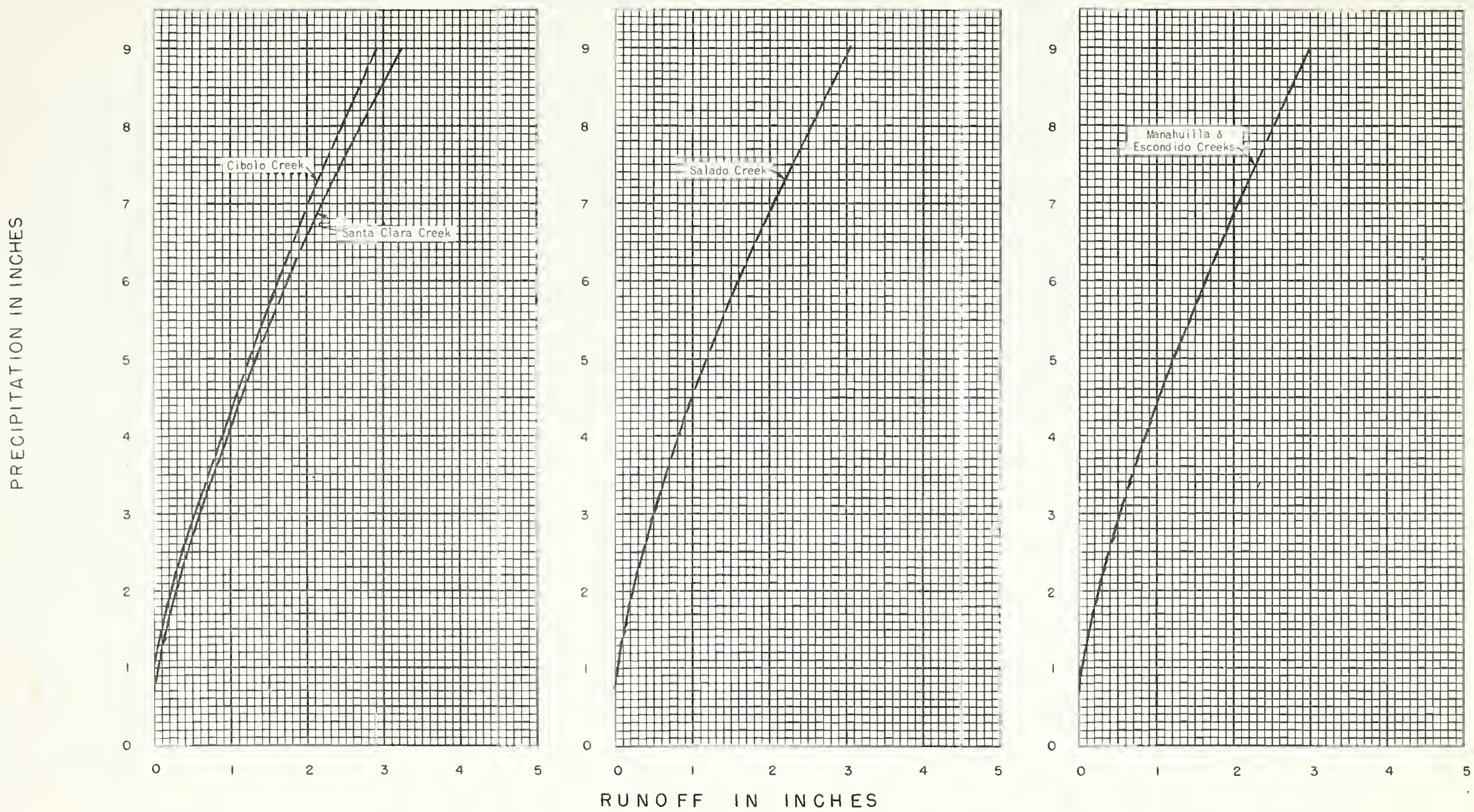

Figure 21
RAINFALL-RUNOFF RELATIONSHIPS
SAMPLE WATERSHEDS-PRESENT CONDITION
SAN ANTONIO RIVER WATERSHED
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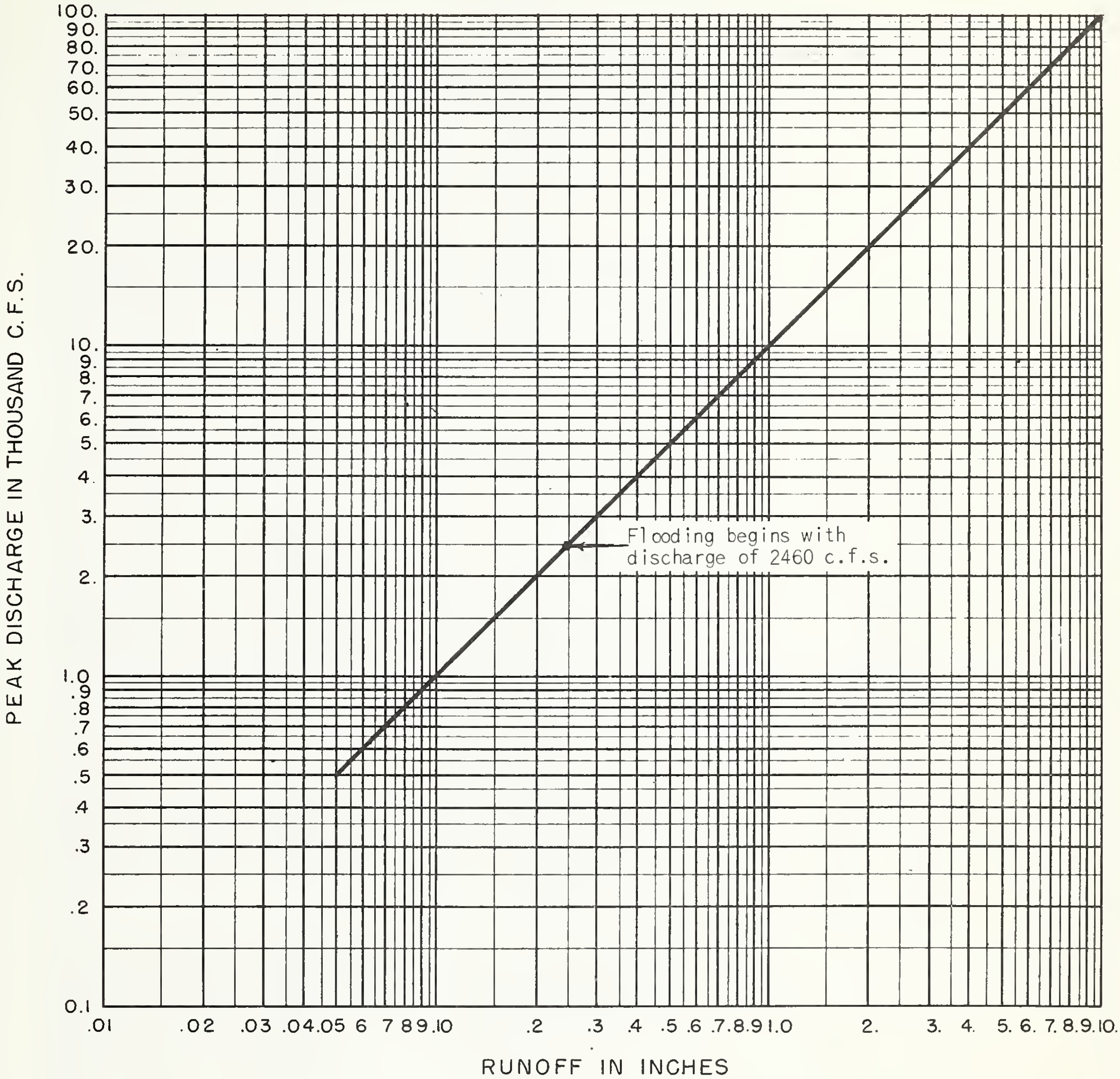

Figure 22
DEPTH OF RUNOFF AND PEAK DISCHARGE RELATIONSHIP FOR CALAVERAS CREEK VALLEY CROSS SECTION NO.1 BEXAR AND WILSON COUNTIES

SAN ANTONIO RIVER WATERSHED

TEXAS

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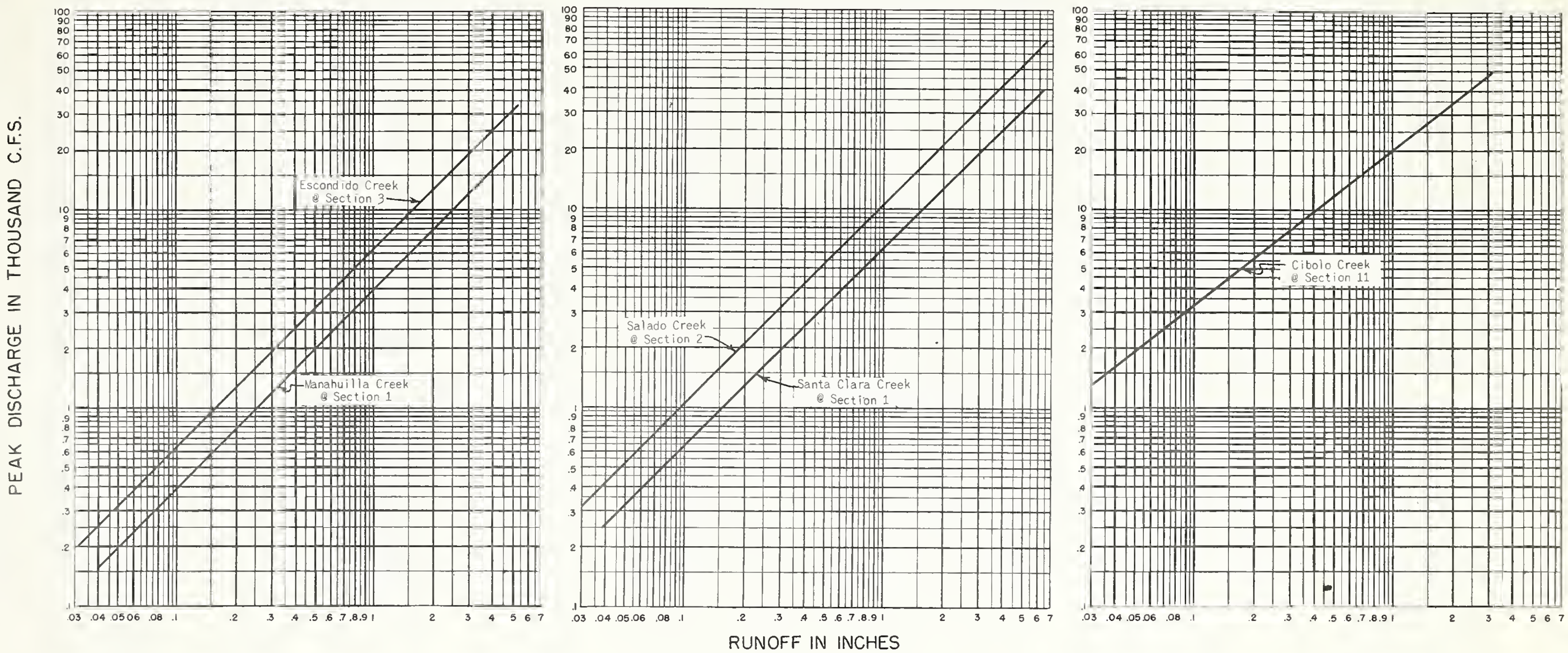

Figure 23

RUNOFF - PEAK DISCHARGE RELATIONSHIPS
SAMPLE WATERSHEDS

SAN ANTONIO RIVER WATERSHED

TEXAS

4-17-52 4-R-8222-34

by the use of the slope-area method and Manning's formula. Precipitation which produced the discharge was determined from records at the San Antonio and Floresville stations. An isohyetal map of the storm precipitation, as developed by the U. S. Geological Survey, also was used to determine the weighted precipitation for the storm of September 1946. The calculated runoff from this storm was adjusted to that from similar gaged areas.

Calculation of Flood Occurrences and Magnitudes

In sample watersheds for which adequate stream gage records were not available the flood series was determined from rainfall records and curves of rainfall-runoff relationships. All storms in the 25-year period (1920-1944) which were capable of producing sufficient runoff to cause flooding in the creeks under consideration were listed. Several storms were eliminated from consideration because they occurred shortly before or after another flood-producing storm. During seasons within which a damaged crop could be replanted, only the storm producing the largest flood within any 15-day period was considered as being damage-producing. These seasons are March through June and the month of October. During the non-replanting seasons of July through September and November through February only the storm producing the largest flood in each season was considered as being damage-producing.

Rainfall on each sample watershed was determined from the records of precipitation stations located in or sufficiently close to the watershed to be used in the Thiessen polygon weighting method. In some watersheds it was necessary to use point rainfall from the nearest precipitation station where breaks in records occurred from some of the stations used in the weighting of precipitation. Figures 12 to 17 show the Thiessen weights used for each.

In creeks having stream gage records the damage-producing flood series was selected directly from stream discharge records. The procedure for the elimination of non-damaging floods was the same as described above.

Calculation of Stream Discharge and Area Inundated

Stream discharges and the corresponding depth of overbank flow were computed for selected depths, from bankfull to the maximum flood stage, at each valley cross-section. Table 23 shows a typical computation used in the solution of Manning's formula for stream flow. The relationship between discharge and stage was plotted for each cross-section as shown in figure 24 for cross-section number 1.

The relationship between a given discharge at the valley cross-section used for reference and the corresponding discharges at other points along the stream was established by use of the theory of concordant flow. In this theory it is considered that the maximum rate of

Table 23. Stream Discharge Computations for Valley Cross-Section No. 1
Calaveras Creek, Bexar and Wilson Counties

San Antonio River Watershed, Texas

Elevation of Water Surface feet	CHANNEL SECTION $n = .07$; $s_1 = .00160$; $s^{\frac{1}{2}} = .0400$						OVERFLOW SECTION $s_1 = .00145$; $s^{\frac{1}{2}} = .03807$							TOTAL
	Area of Section sq. ft.	Width of Water Surface feet	Wetted Perimeter feet	Hydraulic Radius a/p		$\frac{1.486\ ar^{2/3}s^{1/2}}{n}$	Area of Section sq. ft.	Width of Water Surface feet	Wetted Perimeter feet	Hydraulic Radius a/p		Coefficient of Roughness	$\frac{1.486\ ar^{2/3}s^{1/2}}{n}$	Overflow and Channel Section Combined
m.s.l.	a	L	p	r	$r^{2/3}$	Q	a	L	p	r	$r^{2/3}$	n	Q	Q
394.5 1/														0
404.0	460	75.0	79.0	5.82	3.23	1,270								1,270
407.5	880	129.0	133.7	6.58	3.51	2,620								2,620
409.5 2/	1,140	149.0	154.8	7.36	3.78	3,660								3,660
411.0	1,420	155.0	161.8	8.78	4.26	5,140	2,870	2,795	2,795	1.03	1.02	.045	3,680	8,820
413.0	1,800	170.0	177.7	10.13	4.68	7,150	9,670	3,870	3,870	2.50	1.84	.050	20,130	27,280
416.0	2,380	205.0	213.3	11.16	4.99	10,080	11,860	4,360	4,360	4.94	2.90	.052	67,930	78,010
417.5	2,760	225.0	233.5	11.82	5.19	12,160	28,150	4,675	4,675	6.02	3.31	.052	101,370	113,530

1/ Bottom of Channel.

2/ Flooding Begins.

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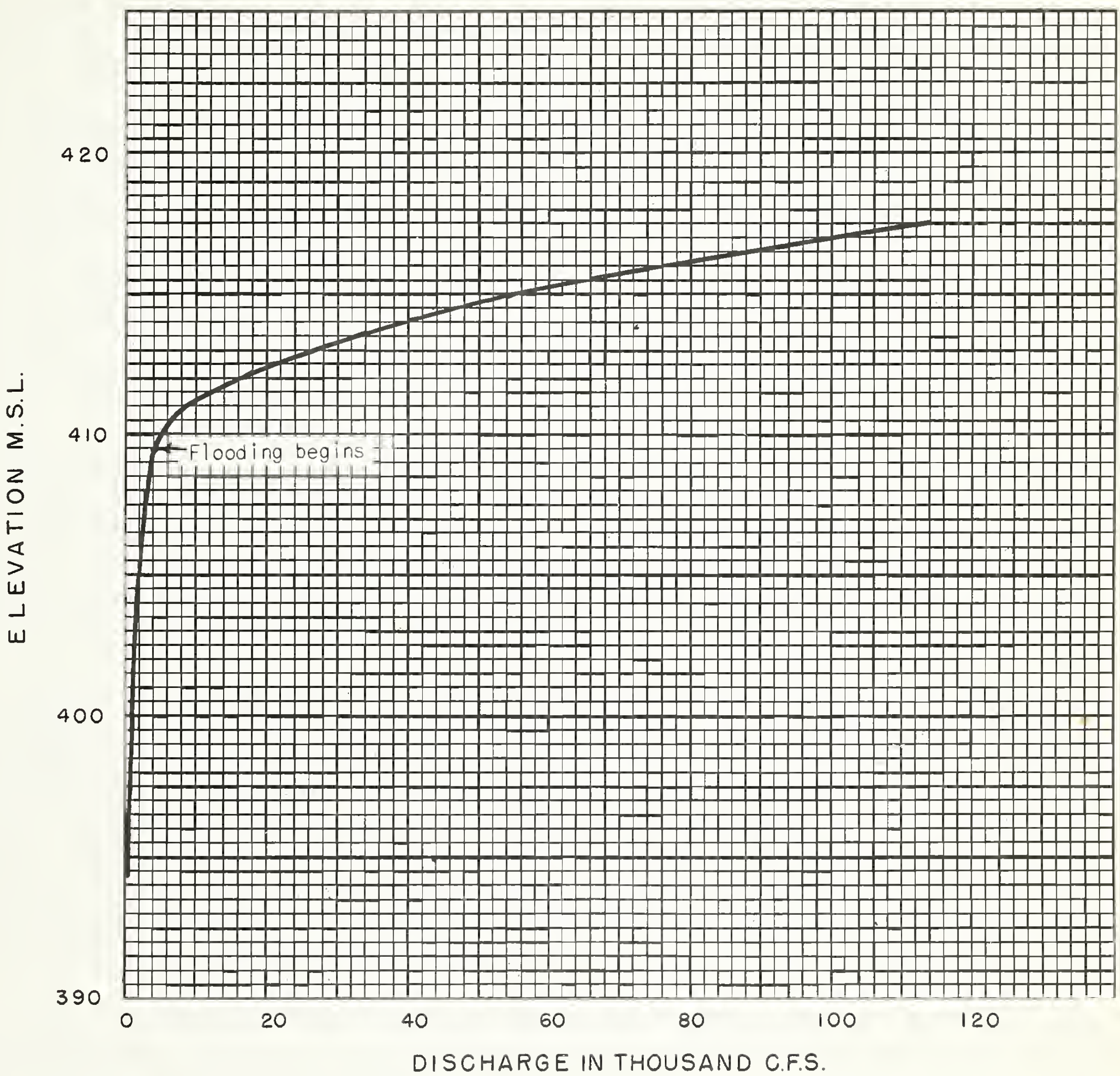

Figure 24
DEPTH OF FLOODING
IN RELATION TO STREAM DISCHARGE RATE
AT VALLEY CROSS SECTION NO. 1, CALAVERAS CREEK
BEXAR AND WILSON COUNTIES

SAN ANTONIO RIVER WATERSHED

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discharge varies between different points with the ratio of drainage areas raised to some exponential power. The exponent reflects the effects of drainage pattern, uniformity of supply and valley storage in the contributing area. The values of the exponent may range from negative to fractional positive figures which approach unity as a limit. Selection of the proper concordant flow exponent is made by a study of high water marks and the corresponding discharges at various points along the stream. The exponents were also checked by references to the relationship between flood discharge in c.s.m. per inch of runoff to drainage area as indicated by gaged records in and near the San Antonio River Watershed. For Calaveras Creek exponents of 0.5 and 0.85 were developed for the purpose of relating discharge at the reference section to other points, as shown in table 24. The smaller exponent was used for the area exceeding 24 square miles and the higher for the upper portion of the watershed. Using the 0.5 exponent in the headwaters would result in computed discharges that exceed the maximum shown by stream gage records.

To facilitate the determination of the relationship existing between discharge and the corresponding area flooded the streams were divided into reaches, or segments of valleys, of homogeneous hydraulic characteristics. At a point selected as being representative of each reach a valley cross-section was surveyed and plotted for use in computing the stage-area inundated relationship.

The area inundated was computed for selected stages from bankfull to maximum flood. The width of water surface for selected stages was determined for each valley cross-section similar to section 2, as shown in figure 25. The width of water surface was converted to acres flooded in the reach, for each selected stage, by multiplying by the length of reach. The resulting curve for section number 1 in Calaveras Creek is shown in figure 26. Areas within well defined channels, depressed areas adjacent to channels, and areas of very shallow depths of flooding were not included in the area inundated.

The concordant flow factors and cross-section rating curves already described were used to determine the stage at each cross-section properly associated with the stage at the reference section. Table 24 shows the area inundated by depth increments for a flood at elevation of 412.2 feet at valley cross-section 1. The areas flooded by depth increments were determined for selected depths from the stage-area curves for each cross-section.

Areas flooded by unsurveyed streams in the sample watershed were determined by proration from surveyed areas. A field examination was made of the unsurveyed areas and it was then determined which reaches of the surveyed areas were similar to unsurveyed areas.

The effect of duration of flooding was not evaluated, since the hydrographs for the areas investigated are very sharp and the variations in short periods of inundation would not affect damages or benefits significantly.

Table 24. Area Inundated by Flood With Water Surface Elevation of 412.2 m.s.l. at Valley Section 1 Calaveras Creek

San Antonio River Watershed, Texas

Sect. No. 1/	Drainage Area (sq.mi.)	Concordant Flow Factor 2/	Peak Discharge (c.f.s.)	Water Surface Elevation (m.s.l.)	Total Area Flooded 3/ (acres)	Area Flooded at Various Depths 3/ 0-1.0' (acres)	1.1'-3.0' (acres)	3.1' & Above (acres)
1	87.49	1.000	19,640	412.2	483	86	397	0
2	85.11	.985	19,350	426.1	295	29	167	99
3	82.38	.972	19,100	430.2	116	11	34	71
4	63.71	.853	16,750	437.0	109	15	58	36
5	33.84	.626	12,300	445.2	34	4	8	22
6	31.92	.606	11,900	457.2	115	8	41	66
7	23.96	.530	10,400	466.7	53	17	18	18
8	18.09	.405	7,950	477.9	121	19	78	24
9	13.88	.326	6,400	496.6	54	9	45	0
10	7.89	.199	3,900	517.3	0	0	0	0
11	5.67	.150	2,950	555.3	63	32	31	0
12	3.83	.106	2,080	576.9	0	0	0	0
13	28.79	.577	11,340	445.0	81	43	38	0
14	27.97	.567	11,140	457.2	55	8	12	35
15	25.76	.522	10,260	465.6	118	14	69	35
16	22.96	.502	9,860	477.2	226	10	216	0
17	21.18	.468	9,200	486.2	116	24	92	0
18	13.18	.313	6,140	505.3	94	18	61	15
19	8.27	.207	4,060	513.3	22	7	11	4
20	7.19	.185	3,640	527.0	0	0	0	0
21	16.60	.377	7,400	443.3	143	29	114	0
22	14.58	.336	6,600	452.7	46	22	24	0
23	7.41	.188	3,700	466.0	14	7	7	0
24	6.58	.175	3,440	480.3	11	2	3	6
4/	-	-	-	-	148	68	68	12
Totals	-	-	-	-	2,517	482	1,592	443

1/ Sections 1-12 on Calaveras Creek; Sections 13-20 on Chopaderos Creek and Sections 21-24 on Parita Creek.
2/ Based on ratio of drainage area raised to 0.50 power for drainage area exceeding 24 square miles, and 0.85 power less than 24 square miles.
3/ From stage-area curves.
4/ Prorated areas on minor headwater streams similar to surveyed stream.

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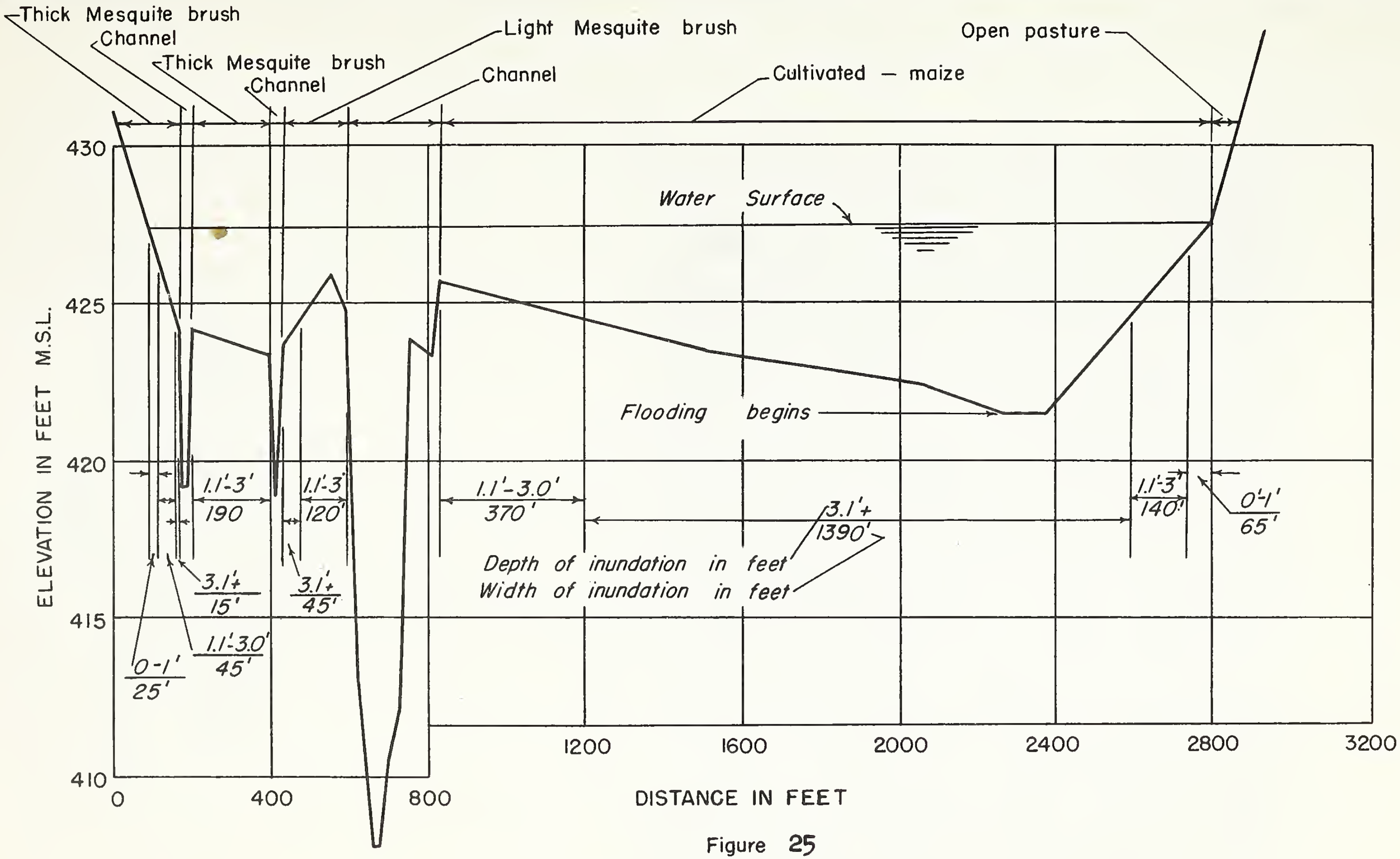

Figure 25
VALLEY CROSS-SECTION NO. 2
CALAVERAS CREEK
SHOWING FLOOD PLAIN INUNDATION
SAN ANTONIO RIVER WATERSHED
TEXAS

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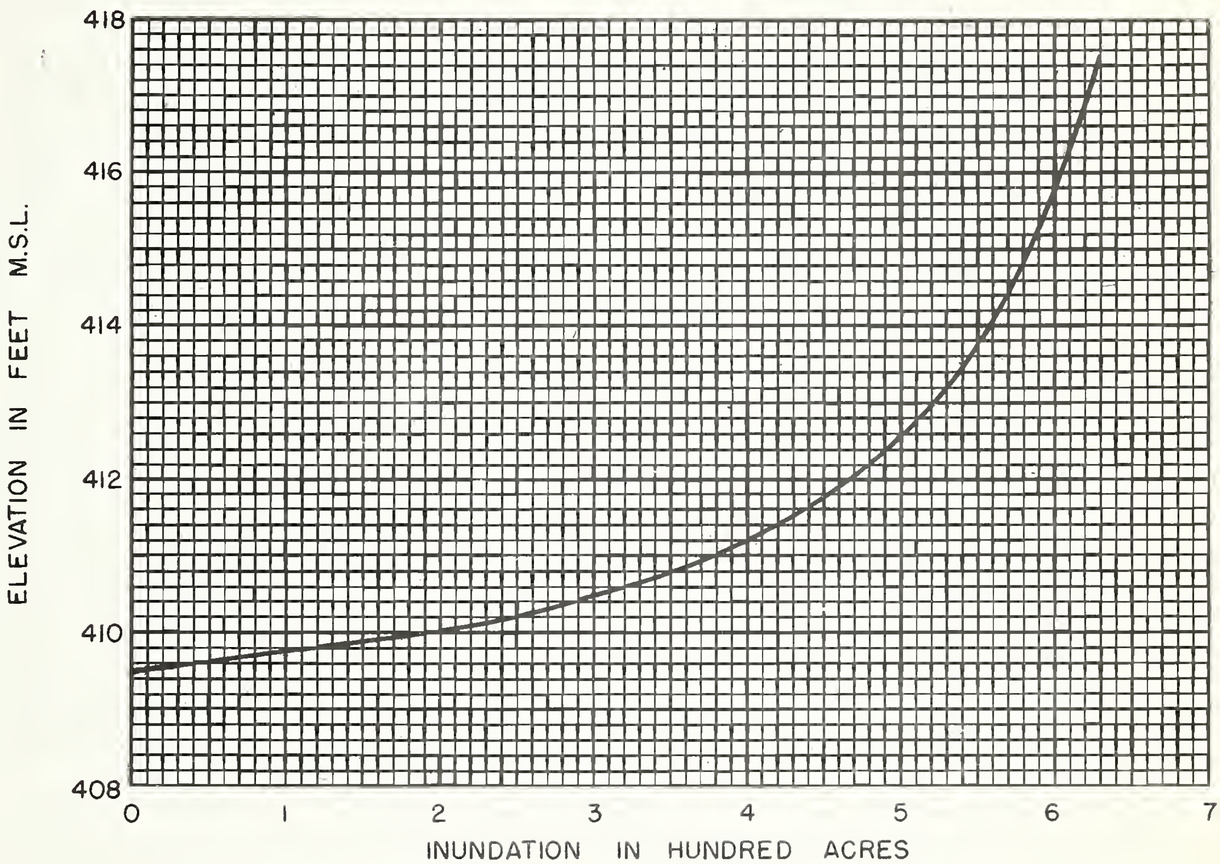

Figure 26
AREA INUNDATED AT
VARIOUS LEVELS OF FLOODING
VALLEY CROSS-SECTION NO. 1 FOR REACH NO. 1
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
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The expected modification of the peak rates of discharge by the installation of floodwater retarding structures (flood prevention measures) is shown for 2.00 inches of runoff in table 25.

In this illustration uncontrolled drainage area refers to those parts of the watershed which do not drain into the proposed floodwater retarding structures. It was assumed that the reduction in the peak rate of discharge of a stream was proportional to the percentage of the watershed draining into the proposed floodwater retarding structures. The reduced peak rate of discharge was determined by multiplying the peak rate before installation of the structures by the percentage of watershed representing the uncontrolled drainage area and adding to the product the release discharge from structures. In this sample watershed it was assumed that detained floodwaters will be released at a rate not to exceed 4 cubic-feet per second per square mile of drainage area.

The peak rate of stream discharge as modified by floodwater retarding structures was calculated for a number of selected depths of runoff in the manner described. The corresponding areas inundated by depth increments, as related to the overbank stage of flood, were read from the stage-area curves and the resulting damage was computed. These values for area flooded were plotted opposite the runoff in the same manner as already described for obtaining the runoff-area inundated relationship curve shown in Appendix IV.

This procedure as described for Calaveras Creek was used for all sample watersheds.

In the preceding discussion, references to the recommended program imply the use of various combinations of measures in different watersheds. The effect of installation of land treatment measures was evaluated in all sample watersheds. The proposed amounts of these measures vary between watersheds, and the effect of such variation is reflected in the rainfall-runoff relationship developed for each. The effect of floodwater retarding structures on area inundated was evaluated in all sample watersheds where such structures are proposed.

Areas inundated by each flood of the flood series investigated for Calaveras Creek under present conditions and as modified by recommended land treatment and stabilizing measures and floodwater retarding structures are shown in table 30, Appendix IV.

Figure 38, Appendix V shows the six divisions of the San Antonio River Watershed to which data from the sample watersheds was expanded. The acres and percent of land area of each of these divisions, as well as for the San Antonio River main stem and lower Cibolo Creek, which would be flooded by the largest flood in the damage-producing flood series is shown in the following tabulation:

Table 25. Peak Discharges After Installation of Floodwater Retarding Structures 1/ Calaveras Creek

San Antonio River Watershed, Texas

Valley Cross-Section Number 2/	Drainage Area: Controlled (sq.mi.)	Drainage Area: Uncontrolled (percent)	Discharge: Before Installation of Structures (c.f.s.)	Discharge: From Uncontrolled Drainage Area (c.f.s.)	Discharge: Release From Structures (c.f.s.)	Discharge: After Installation of Structures (c.f.s.)
24	6.66	0	3,440	0	27	27
23	6.66	10.1	3,700	374	27	401
22	6.66	54.3	6,600	3,584	27	3,611
21	6.66	59.9	7,400	4,433	27	4,460
20	0	100.0	3,640	3,640	0	3,640
19	0	100.0	4,060	4,060	0	4,060
18	0	100.0	6,140	6,140	0	6,140
17	20.84	0	9,200	0	83	83
16	20.84	9.2	9,860	907	83	990
15	20.84	19.1	10,260	1,960	83	2,043
14	20.84	25.5	11,140	2,841	83	2,924
13	20.84	27.6	11,340	3,130	83	3,213
12	0	100.0	2,080	2,080	0	2,080
11	5.58	0	2,950	0	22	22
10	5.58	29.4	3,900	1,147	22	1,169
9	7.79	44.0	6,400	2,816	31	2,847
8	9.41	48.0	7,950	3,816	38	3,854
7	14.18	40.9	10,400	4,254	57	4,311
6	20.01	37.3	11,900	4,439	80	4,519
5	20.01	40.8	12,300	5,018	80	5,098
4	40.85	35.9	16,750	6,013	163	6,176
3	47.51	42.3	19,100	8,079	190	8,269
2	47.51	44.2	19,350	8,553	190	8,743
1	47.51	45.7	19,640	8,975	190	9,165

1/ For storm producing 2.00 inches of runoff above valley cross-section 1.

2/ Numbers 1-12 on Calaveras Creek Main Stem; 13-20 on Chopaderos Creek; 21-24 on Parita Creek.

Location 1/	Acres	Percent
Area 1, Like Cibolo Creek above Selma Gage	17,100	2.60
Area 2, Like Salado Creek	8,200	1.78
Area 3, Like Santa Clara Creek	15,500	12.30
Area 4, Like Calaveras Creek	16,700	4.62
Area 5, Like Escondido Creek	18,500	4.01 2/
Area 6, Like Manahuilla Creek	11,600	2.34
San Antonio River, Main Stem	90,965	
Cibolo Creek, below Selma Gage, Main Stem	5,100	

1/ Refers to figure 38, Appendix V.
2/ Excluding area of Corps of Engineers recommended project.

The relationship between flood magnitude and flood plain area inundated was developed for each sample watershed. Figure 27 shows this relationship for Calaveras Creek and figure 28 includes the remaining 5 sample watersheds investigated. These curves indicate that the majority of floods inundate only a small portion of the maximum flood plain. Out of a total of 54 floods on Calaveras Creek, 29 inundated an area from 1 to 540 acres; 13 floods inundated from 541-1105 acres; 8 floods inundated from 1106-1690 acres; and only 4 floods exceeded 1690 acres of inundation.

Floodwater Retarding Structures

Field reconnaissance, site surveys and additional analysis reveal that systems of floodwater retarding structures are feasible in a number of the creek watersheds. Areas in which floodwater retarding structures are recommended are shown in figure 39, Appendix V.

Floodwater retarding structures were designed to have a detention capacity approximating the volume of runoff to be expected from a 25-year frequency storm. For Calaveras Creek the expected average depth of runoff used, for such a storm, was 4.60 inches. The minimum volume of reserve storage capacity provided was equal to the volume of sediment expected within 50 years. In areas where sediment contribution rates

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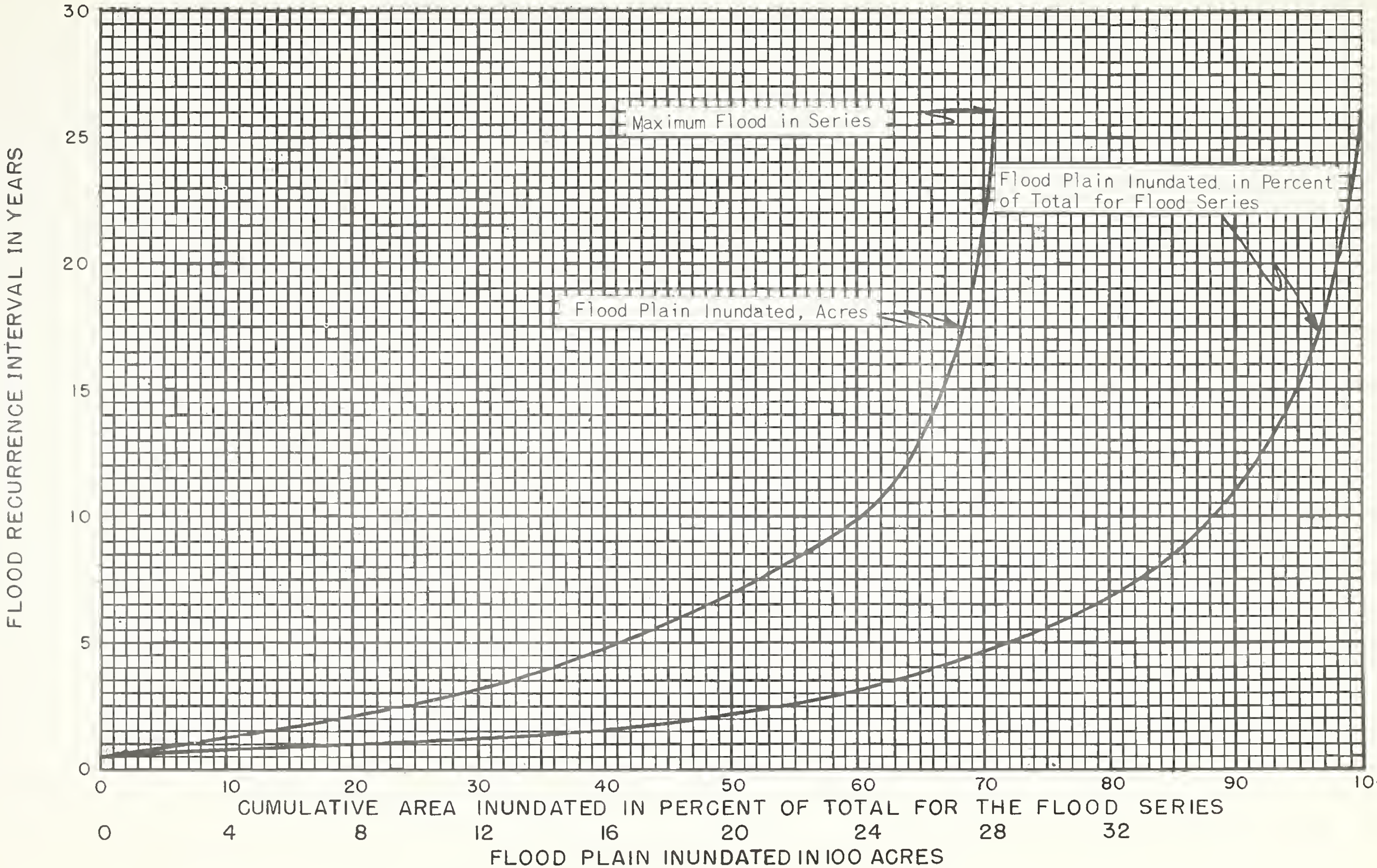

Figure 27
AREA INUNDATED BY FLOODS
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

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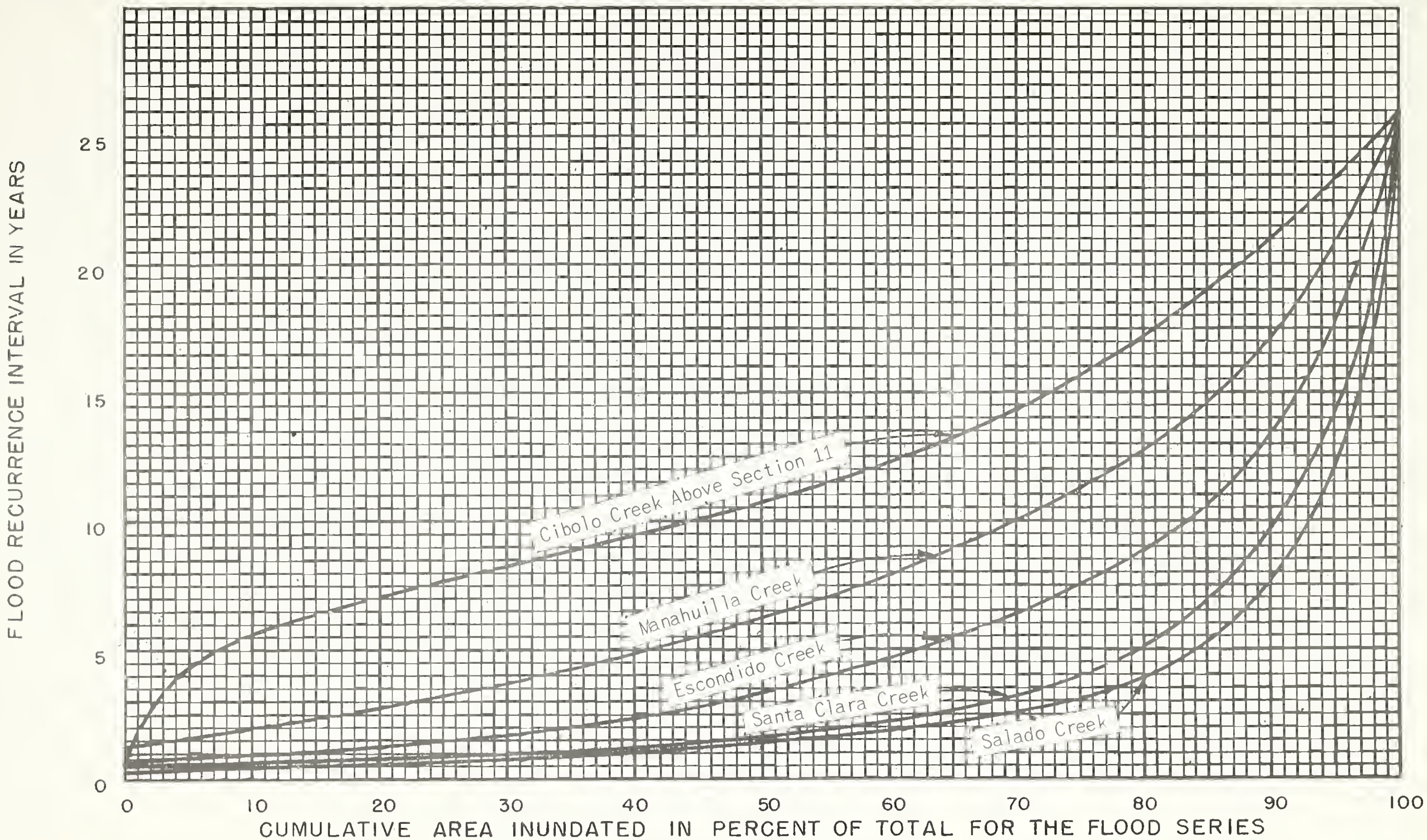

Figure 28

AREA INUNDATED BY FLOODS IN SERIES

SAMPLE WATERSHEDS

SAN ANTONIO RIVER WATERSHED

TEXAS

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are now high, floodwater retarding structures should not be constructed until the needed land treatment measures have been applied and the rates reduced. A permanent storage pool not more than 12 feet in depth will be provided for stockwater and other purposes.

Detention pools will empty through uncontrolled drop-inlet type discharge structures at a rate not exceeding 4 second-feet per square mile of drainage area. Figure 29 indicates the effect of storage volume on release rates.

Estimated costs of floodwater retarding structures were based on the following general design critieria:

Drainage Area Controlled by Structures, Square-Miles	Frequency-Volume of Runoff Controlled
0-5.9	25-year frequency
6.0-10.9	25-100 year frequency
11.0 plus	100-year frequency

Estimates of costs for structures were made assuming all would have rolled earth fill with the exception of one large reservoir site on Cibolo Creek where rock fill was considered. Spillways were designed according to Texas State Board of Water Engineers requirements. Concrete emergency spillways were considered on structures with drainage areas exceeding eleven square miles and which had insufficient detention capacity to contain the 100-year frequency flood. Vegetative spillways were provided for structures where required volumes were available.

The investigation of floodwater retarding structures included necessary relocation or elevation of roads, relocation of farmsteads, storage volume and surface area in various pools and the amount of embankment.

Pertinent data and number of structures included in the recommended program are given in Appendix V. Information regarding surveyed floodwater retarding structure sites in the Calaveras Creek sample watershed is included in the following tabulation.

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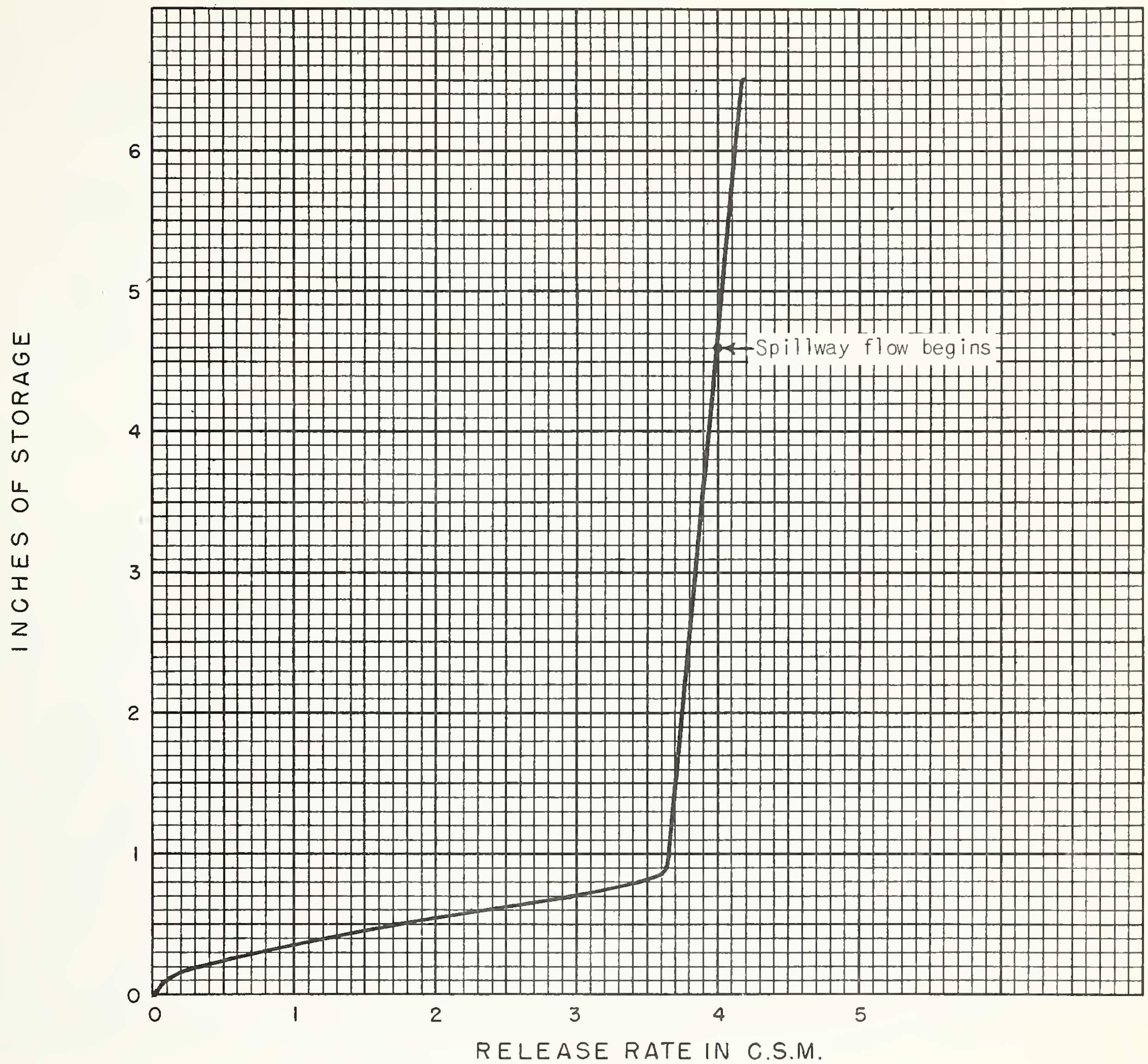

Figure 29
RATING CURVE
FOR RELEASE TUBE ON RETARDING STRUCTURE NO.9
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

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Site No.	Drainage Area	Detention Pool		Storage Volume: Permanent Pool	Reserve	Total	Surface Area: Top of Permanent Pool	Surface Area: Spillway Elevation	Embankment
	(sq.mi.)	(inches)	(ac.ft.)	(ac.ft.)	(ac.ft.)	(ac.ft.)	(acres)	(acres)	(cu.yds.)
2	5.83	4.6	1,430	187	0	1,617	44	177	66,817
3	1.62	4.6	398	69	0	467	27	63	43,416
4	2.21	4.6	542	82	0	624	19	75	62,469
8	5.58	4.6	1,369	179	0	1,548	53	160	127,510
9	4.77	4.6	1,170	165	0	1,335	37	155	76,199
16	20.84	8.8	9,781	356	146	10,283	75	820	299,584
18	6.66	4.6	1,634	114	99	1,847	25	182	63,539
Total	47.51 1/		16,324	1,152	245	17,721	280	1,632	739,534

1/ This is 49.5 percent of the 96.0 square miles drainage area in the sample watershed

Effects of the Recommended Program on Water Resources

Since surface water resources are used for much of the irrigation in the San Antonio River Watershed, the probable effects of the recommended program on surface water resources are discussed in Appendix VII. Table 58, Appendix VII shows that approximately 50 percent of the increased volume of water expected to be infiltrated due to land treatment can be expected to percolate to deep ground water aquifers and will result in a loss of 9-11 percent of present surface water resources at selected gaging stations. In addition, the net evaporation from the permanent pools of recommended floodwater retarding structures would reduce the present annual yields of runoff at selected stations by approximately 1 percent.

Floods on the San Antonio River and Lower Cibolo Creek Main Stems

An investigation was made of the areas inundated along the main stem on the San Antonio River from the city limits of San Antonio to the mouth of the river, and along Cibolo Creek below the Selma stream gaging station. Four major reaches as previously used by the Corps of Engineers, figure 30, were considered on the San Antonio River. The area above reach 4 on the San Antonio River was excluded, as this is the area where the recommended project of the Department of the Army, Corps of Engineers 1/, is to be installed.

The area inundated in the main stem reaches investigated was based on stream discharge data collected and published by the U. S. Geological Surveys. In addition, the rainfall-runoff relationships curve was used to estimate peak discharges for periods when gaging stations were not in operation.

1/ Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas, Department of the Army, Corps of Engineers.

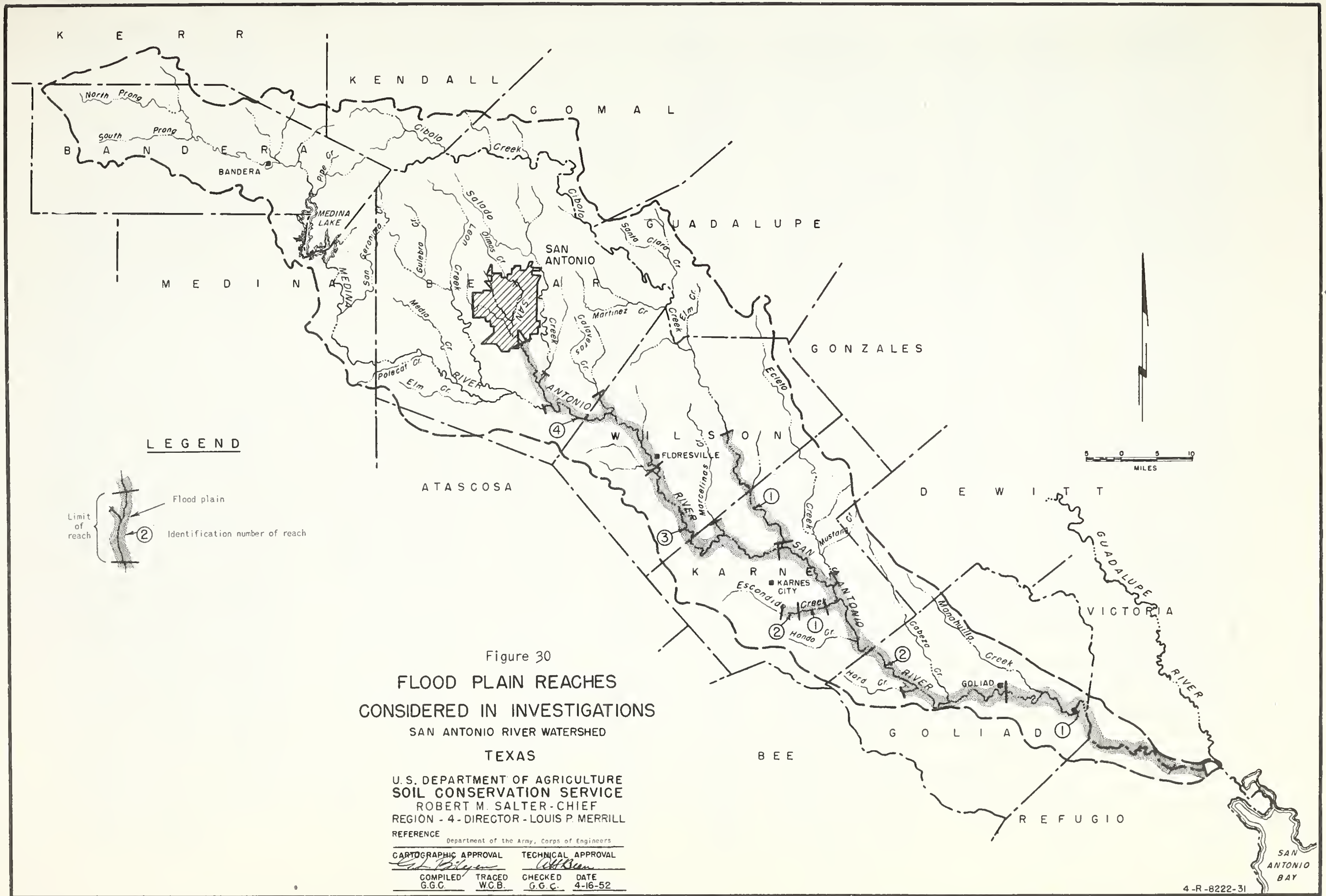

Figure 30

FLOOD PLAIN REACHES
CONSIDERED IN INVESTIGATIONS

SAN ANTONIO RIVER WATERSHED

TEXAS

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REFERENCE Department of the Army, Corps of Engineers

CARTOGRAPHIC APPROVAL TECHNICAL APPROVAL

COMPILED G.G.C. TRACED W.C.B. CHECKED G.G.C. DATE 4-16-52

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Reductions in peak discharges due to the installation of recommended floodwater retarding structures were based on the percent of watershed area controlled by these structures at each main stem valley reach. Releases from the structures were added to the hydrographs of runoff from uncontrolled areas in determining the net reductions.

The reductions in volume of runoff were related to the peak discharges, which in turn were related to stage and area inundated, for all conditions investigated.

Peak discharge-area inundated curves were developed for several reaches so that crop and pasture damages for each flood in the series could be determined, Appendices IV and VI.

Basic Data: Flood routing under present conditions for each of the floods producing damages along the main stems was based on published U. S. Geological Survey stream discharge data on the San Antonio River and Cibolo Creek. The periods of record and other pertinent data are shown in tables 17, 18 and 19. Rainfall-runoff and depth-area relationships and high water marks were also used where stream discharge data was not available.

Engineering data from the Corps of Engineers, U. S. Army, were made available for the four major reaches on the San Antonio River. These data included the following information:

1. Detailed maps showing general physical features, outline of the flood plain, location of some of the valley cross-sections and location and extent of reaches.

2. Profiles of the river showing the thalweg, elevations of stream banks and high water mark elevations for various floods of record.

3. Profiles of valley and channel cross-sections.

4. Copies of curves for reaches 1 through 4 showing the percent of area inundated in relation to peak discharges.

5. A tabulation showing the area inundated for various reaches and the land use of these areas.

Calculation of Stream Discharge and Area Inundated, Main Stem of San Antonio River: Stream discharges and the corresponding depth of overbank flow were computed for selected depths from bank-full to the maximum flood stage at each of 24 valley cross-sections. These 24 minor reaches make up the 4 major reaches used in the investigation of the San Antonio River main stem. The method used for determining area inundated and the damages for the main stem of the San Antonio River is essentially the same as the method which was used for the Calaveras Creek Watershed. The details of calculations which follow apply to the investigation of the 4 major reaches on the San Antonio River.

The 24 valley cross-sections mentioned above were located on the plotted profiles. At these locations the stages for the various peak discharges as determined by the Corps of Engineers were tabulated. Using these stages and discharges, rating curves were plotted for each of the 24 valley cross-sections.

The elevation of "start of flooding" was taken from the cross-sections secured from the Corps of Engineers. This point for "start of flooding" was then recorded on the rating curve for each of the 24 valley cross-sections. Using the elevations for "start of flooding" as zero, the width of the flood plain for various elevations above this point was measured and tabulated until the maximum flood elevation was reached. The total area inundated at the maximum flood elevation was determined by the Corps of Engineers and this figure was used in this investigation.

Having established the point where flooding begins and the maximum flood plain area, the areas inundated at elevations between zero and 100 percent inundation were then calculated as a percent of the width at each elevation to the maximum width. Using these results, stage-area inundation curves were plotted for each of the minor valley reaches.

Selected floods were routed through the 24 valley cross-sections. From these routings, the areas inundated by various increments of depth were computed for each of the 4 major reaches. The areas inundated by depth increments for each of the major reaches were totaled. The total of all depth increments of flooding was then plotted against the peak discharge at the reference section, as was done in figure 32, Appendix IV. Flooding by depth increments was used to estimate flood damages as explained in Appendix IV.

The area inundated for each flood in the series was determined for present conditions from the routing of all runoff from flood-producing storms through each of the major reaches.

To determine the area inundated for each flood in the series under future conditions with the land treatment program in effect, new rainfall-runoff relationships were developed using the changed acreages of the various soil-cover complexes. This procedure is explained under Rainfall-Runoff Relationships. Using the rainfall-runoff relationships for future land use conditions and the stage-area inundation curves, the area inundated by each flood was determined. The total area inundated for the flood series was obtained and divided by the period of years of the series to obtain the average annual acres inundated.

The effect of the floodwater retarding structures on peak discharge and area inundated was computed assuming that land treatment and stabilizing measures had been applied and were effective. The procedure for determining the effects of the floodwater retarding structures on peak discharges along the main stem of the San Antonio River is essentially the same as that described under Calculation of Stream Discharge and Area Inundated. The flood series and other pertinent data for each of the 4 major reaches are shown in table 36, Appendix IV.

APPENDIX IV

WATERSHED FLOOD PROBLEMS AND RELATED DAMAGES

DESCRIPTION OF FLOOD DAMAGES

Flood damage in creek watersheds is often caused by thunderstorms which are usually characterized by intense precipitation, occur at relatively frequent intervals and cover small portions of the watershed. This flood damage is primarily to crops, pastures and fences with lesser damage to roads, bridges and other property. In the San Antonio River Watershed as a whole flood damage usually results from general storms which originate in the Gulf of Mexico or the Southwestern Highlands and cover a major part of the watershed. These general storms may cause widespread damage both in tributary areas and in the main stem flood plains below. Large quantities of sediment are carried by these large floods and flood plain lands are often scoured and new channels cut by flood flows. Severe damage to crops and pastures, fences, roads, bridges, railroads, buildings and urban property occur in the watershed as a result of flood flows.

The social and economic problems arising from floods in the San Antonio River Watershed are closely related to agricultural and urban flood damages. These problems include direct income losses to farm operators, damage to flood plain lands, loss to local businesses, losses to home owners and tenants, the fears associated with possible future floods and indirect losses which may occur due to the decline in property values and community services.

The amount of damage caused by any flood varies with the severity and extent of the storm and the season of the year in which the flood occurs. Floods in the San Antonio River Watershed have occurred during all months of the year but most frequently in April, May and June. During this season serious damage is done to growing crops and complete loss of mature small grain crops may occur. September and December are months in which floods are next highest in frequency of occurrence and cause damage to mature crops or newly planted crops. Floods occurring during the winter months cause less damage to crops than is caused by floods in other seasons.

Unless preventative work is done, flooding can be expected to increase in frequency of occurrence, magnitude and severity of damage. This will be caused by deterioration of land cover, increased erosion and runoff and continued sedimentation and scour of channels and flood plains.

The annual flood damage in the San Antonio River Watershed, excluding that within San Antonio and Kenedy, amounts to approximately $967,000.

METHODS OF ESTIMATING FLOOD DAMAGES

Area Included in Estimates

No damages, other than sedimentation of reservoirs, were calculated, nor corresponding benefits estimated in the area presently inundated by Medina Lake.

No damages or benefits were estimated in areas within the city of San Antonio or on Escondido Creek from a point at U. S. Highway Number 181 within the city of Kenedy downstream for a distance of approximately 2.4 river miles. In these areas works of improvement have been recommended by the Corps of Engineers. On all other areas flood damages and expected benefits from the recommended program were evaluated.

Flood damages were found to be minor on major portions of the following creek watersheds: Upper Medina River; Salado and Marcelinas Creeks of the Upper San Antonio River; San Geronimo and Leon Creeks of the Lower Medina River; Upper Ecleto Creek; and Cabeza, Manahuilla and Hord Creeks of the Lower San Antonio River. Damages were also found to be minor along the main stem of the San Antonio River from a point near the east boundary of Goliad County downstream to the mouth.

Estimation of Floodwater Damage

Floodwater damage, based on prices and values from 1950, was calculated in sufficient detail to permit estimation of future expected flood damage. The calculation included estimates of damage which would occur both with and without the various phases of the recommended program. Estimates of damage to crops, pasture, other agricultural property, and roads and bridges were based on an analysis of flood damage schedules obtained in the field. Damage schedules were obtained on representative samples ranging from 15 to 90 percent of the flood plain within each sample watershed, depending upon the type and intensity of use and damage. With the exception of sediment damage to reservoirs, the estimates of damages in the creek watersheds were based on studies of six representative sample watersheds.

Floodwater damages were calculated separately for reaches of the main streams and for sample watersheds. The data from sample watersheds were expanded to creek watershed areas of similar characteristics. Estimates of sediment damage to reservoirs were made for the individual reservoir and included in the appropriate creek watershed.

Crop and Pasture Damage: The flood damage to any crop or pasture was computed through the following steps:

1. Determine the difference between the value per acre of the undamaged crop and its value after flooding.

2. Subtract the costs not incurred in growing and harvesting.

3. Add the costs of the extra cultivation caused by floods, or

4. Add the costs of all operations in producing an alternative crop of equal or lesser net value.

5. Subtract the gross value of the alternate crop.

The dollars of net damage per acre were then divided by the original per acre undamaged value of the crop to determine a percent damage factor. For example, the percent damage factor to cotton, flooded at a depth of 1.1-3.0 feet in May, was calculated as follows:

Value of original crop	\$77.20 per acre
Value of original crop after flood	\$21.08 per acre
(1) Gross damage	\$56.12 per acre
(2) Minus expenses saved (harvesting, ginning, etc.)	\$15.18 per acre
	\$40.94 per acre
(3) Plus added expense (extra cultivation)	\$ 1.52 per acre
Net flood damage	\$42.46 per acre

The percent damage factor is therefore \$42.46/\$77.20 times 100, or 55 percent of the net flood damage. The percent damage factor to each crop was determined for months and depths of flooding by the method illustrated above. The monthly percent damage factors were used as a base for application in all creek watersheds and the main stem of the San Antonio River. Monthly percent damage factors were converted to seasonal damage factors by weighting the monthly percentages of each month in the season by the number of flood occurrences of each month as determined from the flood series for each sample watershed.

The major land uses of the flood plain were determined from data obtained from surveyed cross-sections and by analysis of aerial photographs. The percentage of cultivated land occupied by each major crop was computed from field schedules. These schedules also supplied the information from which crop yields were estimated. From these data a composite damage rate per flooded acre was calculated for each season and depth of flooding as illustrated in tables 26 and 27. A composite damage rate per flooded acre was used when field investigations showed that variations in land use at different elevations of a given cross-section were not

Table 26. Composite Damageable Value of Crops and Pasture Per Acre of Flood Plain Calaveras Creek Sample Watershed

San Antonio River Watershed, Texas

Crop Use	Flood Plain in Each Use (percent)	Unit	Yield Per Acre of Crop	Production Per Acre of Flood Plain	Value Per Unit (dollars)	Value of Production (dollars)
Corn	15.0	bu.	34.0	5.100	1.24	6.32
Grain Sorghum	6.0	bu.	37.0	2.220	1.01	2.24
Peanuts	0.6	bu.	25.0	0.150	3.30	0.50
Oats	3.0	bu.	30.0	0.900	0.81	0.73
Meadow	5.9	ton	1.98	1.17	16.22	1.90
Idle Cropland	1.5	-	-	-	-	-
Pasture	64.2	AUM	0.54	0.347	6.43	2.23
						13.92

Table 27. Composite Crop and Pasture Damage Rate per Acre Flooded, by Season and Depth of Flooding, Calaveras Creek Sample Watershed

San Antonio River Watershed, Texas

Crop	Composite Damageable Value Per Acre (dollars)	Depth 0 - 1.0' Damage Factor (percent)	Depth 0 - 1.0' Net Damage (dollars)	Depth 1.1' - 3.0' Damage Factor (percent)	Depth 1.1' - 3.0' Net Damage (dollars)	Depth 3.1' and Over Damage Factor (percent)	Depth 3.1' and Over Net Damage (dollars)
March, April, May and June							
Corn	6.32	26	1.64	38	2.40	53	3.35
Grain Sorghum	2.24	21	0.47	33	0.74	50	1.12
Peanuts	0.50	4	0.02	11	0.06	16	0.08
Oats	0.73	26	0.19	43	0.31	55	0.40
Meadow	1.90	24	0.46	27	0.51	40	0.76
Pasture	2.23	10	0.22	18	0.40	21	0.47
Total	13.92		3.00		4.42		6.18
July, August, September and October							
Corn	6.32	15	0.95	31	1.96	48	3.03
Grain Sorghum	2.24	13	0.29	28	0.63	42	0.94
Peanuts	0.50	26	0.13	53	0.27	63	0.32
Oats	0.73	1	0.01	7	0.05	10	0.07
Meadow	1.90	8	0.15	21	0.40	30	0.57
Pasture	2.23	5	0.11	8	0.18	10	0.22
Total	13.92		1.64		3.49		5.15
November, December, January and February							
Corn	6.32	2	0.13	8	0.51	11	0.70
Grain Sorghum	2.24	2	0.04	4	0.09	6	0.13
Peanuts	0.50	5	0.03	9	0.05	15	0.08
Oats	0.73	3	0.02	9	0.07	25	0.18
Meadow	1.90	0	0.00	6	0.11	11	0.21
Pasture	2.23	5	0.11	8	0.18	10	0.22
Total	13.92		0.33		1.01		1.52

significant. Where land use varied significantly by elevations, crop and pasture damages were adjusted accordingly. A stream was divided into reaches, and a composite damage rate was calculated for each reach where significant differences were found in the land use of the flood plain along the length of the stream.

Flood Plain Scour Damage: The physical land damage due to scour was determined by investigation of the stream valleys. It was estimated that scour damage for the San Antonio River Watershed occurs in about a ten-year cycle from the original damage to recovery and that the amount of damage is not increasing appreciably in most areas but has tended to reach a state of equilibrium. The damage to land is in addition to crop and pasture damage estimates since estimates of the yields used in crop and pasture damage evaluation are based on conditions existing at the present time, inclusive of the scoured areas.

The report of the damage appraiser listed the acreage damaged and the degree of damage. The following calculations are illustrative of the procedure used in determining scour damage to land under present watershed conditions:

Calaveras Creek Sample Watershed

17.4 acres damaged annually by 10 percent.

76.4 acres damaged annually by 25 percent.

24.4 acres damaged annually by 50 percent.

6.8 acres damaged annually by 75 percent.

$13.13 = annual per acre value of production less variable costs (variable costs are those production costs that vary with difference in yield).

10 percent of $13.13 x 17.4 = $22.85 net value of production loss on area damaged 10 percent, year of original damage.

25 percent of $13.13 x 76.4 = $250.78 net value of production loss on area damaged 25 percent, year of original damage.

50 percent of $13.13 x 24.4 = $160.18 net value of production loss on area damaged 50 percent, year of original damage.

75 percent of $13.13 x 6.8 = $66.96 net value of production loss on area damaged 75 percent, year of original damage.

$22.85 + $250.78 + $160.18 + $66.96 = $500.77 net value of production loss on total area, year of original damage.

4.723 = present worth of $1.00 decreasing at a constant annual rate to 0 in a 10-year period.

4.723 x $500.77 = $2,365 average annual scour damage.

An index of flooding was used to determine scour damage under future watershed conditions. The total acreage flooded during the period of record under present conditions was taken as 100 percent. Total acres flooded with the going program, with complete land treatment and stabilizing measures and with the recommended program were expressed as percentages of the present acres flooded, table 28. The present damage was then multiplied by these percentages to derive the damage under future treated conditions. Installation of the recommended program will have a beneficial effect by reducing the number of acres scoured annually to less than the acreage of annual recovery.

Other Agricultural Damage: Estimates of other agricultural damage were based on field damage schedules. Damages to fences, livestock, buildings, stored crops, farm roads and bridges and similar agricultural property were tabulated. The totals were converted to a per acre figure by dividing the acres flooded into the total damage from each flood. The per acre damage rate was then correlated with the size of the flood in proportion to the flood plain inundated by the maximum flood in the flood series. Per acre damages from the floods were plotted against the percentages of the flood plain inundated to arrive at a percentage inundated-damage relationship. The curve for Calaveras Creek sample watershed is shown in figure 31.

Nonagricultural Damage: Road, bridge and railroad damage data were obtained from farmers, county road commissioners, state highway maintenance departments and railroad companies. The items damaged were definitely located to preclude duplication. The total damage estimated from a specific flood in a sample watershed was divided by the acreage inundated to arrive at the damage value per acre for that flood. Per acre damages for several floods were plotted against the percentage of flood plain inundated to arrive at a percentage inundated-damage relationship. The curve for Calaveras Creek sample watershed is shown in figure 31.

Nonagricultrual damages along the main stem of the San Antonio River and Lower Cibolo Creek were taken from the Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas 1/.

Urban damages evaluated in the creeks tributary to the San Antonio River are relatively small. Estimates of this type of localized damage were obtained from city officials, files of local newspapers and individuals familiar with local history. Urban damage and nonagricultural damage data used on the main stem of the San Antonio River were taken from the investigations made by the Corps of Engineers 1/.

Information on flood damages to industrial installations, such as pipe lines and oil pumping stations, was obtained through interviews with local field personnel in charge of the installations.

1/ Corps of Engineers, Department of the Army, October 1950, Unpublished.

Table 28. Index of Area Flooded Under Present Conditions and With Phases of the Recommended Program Installed San Antonio River Watershed, Texas.

Sample Watershed	Flood Index - Percent			
	Under Present Conditions	With Going Land Treatment Measures	With Complete Land Treatment and Stabilizing Measures	With Land Treatment and Floodwater Retarding Structures
Calaveras Creek	100	80.8	64.6	12.0
Salado Creek	100	90.9	80.5	52.3
Escondido Creek	100	92.4	85.8	34.4
Santa Clara Creek	100	90.4	73.5	65.2
Manahuilla Creek	100	89.4	81.7	36.3
Upper Cibolo Creek	100	89.0	81.0	35.6

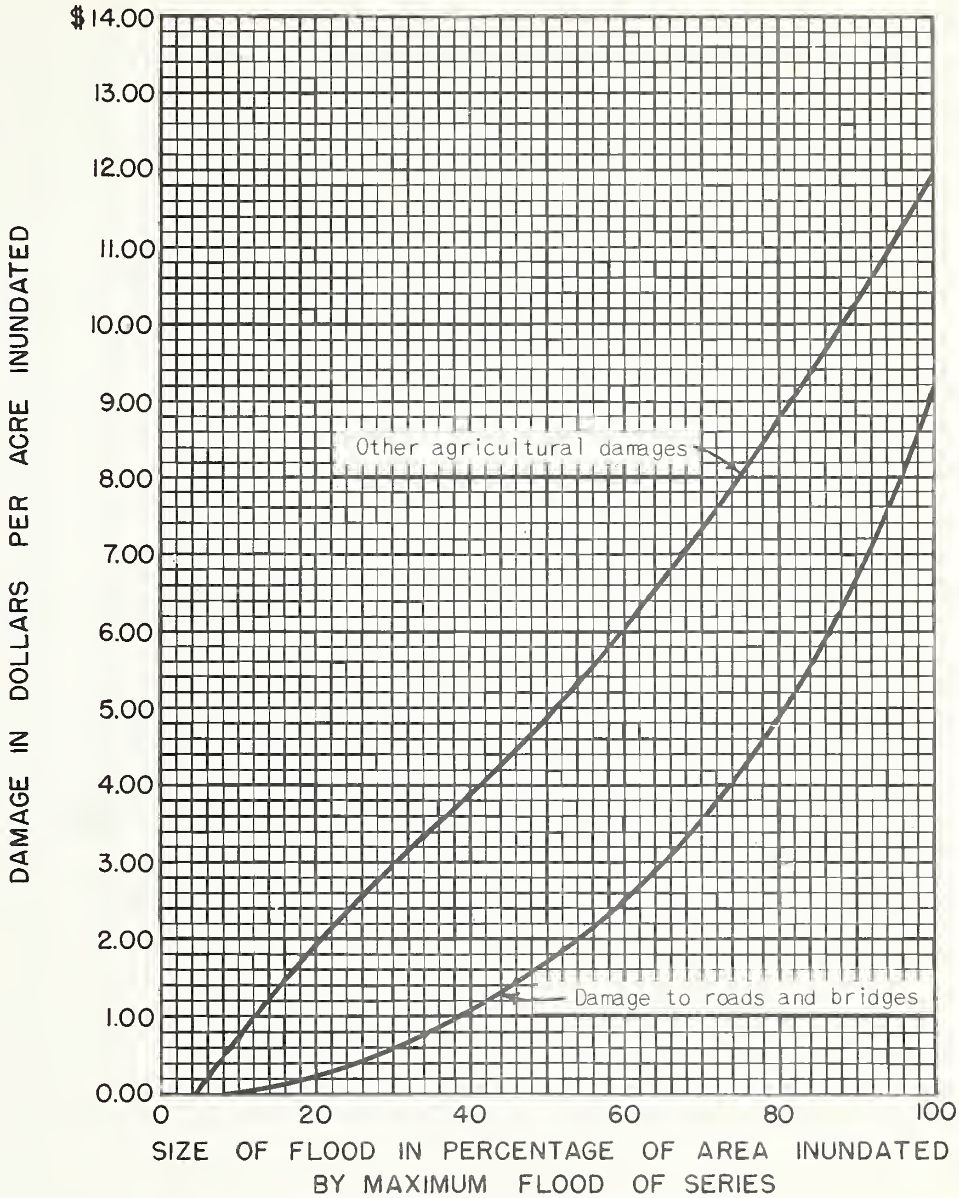

Figure 31

FLOOD DAMAGE TO ROADS AND BRIDGES
AND
OTHER AGRICULTURE DAMAGES
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

W.C.B. 4-9-52 4-N-8222-23

Stream Bank Erosion Damage: Estimates of the acres of flood plain land damaged annually by stream bank erosion were based on reconnaissances of the stream valleys and on valley cross-sections. The annual loss of net income was capitalized to determine the annual rate of damage. As the annual damage from stream bank erosion is relatively small and no special measures for alleviation of the damage appear feasible at this time, future damages are assumed to be the same as at the present. Loss of production in the future from this source was considered in estimating crop and pasture damage.

Indirect Damage: Flood damages to crops cause an indirect damage through loss of business in the community. For example, if part of a cotton crop is destroyed, cotton gins and compresses will lose a part of their normal profits and workers in the gins will suffer loss of wages. Available information 1/ on relationships between the volume of business and the profits and labor earnings were analyzed and curves were constructed showing the relationship of indirect damage of this type to direct damages. Other indirect damages attributable to floods include losses as a result of delay or rerouting of travel and transportation, relief and rehabilitation of flood victims, and similar items. These damages were estimated from the best available information that could be obtained.

Valley Sediment Damage: The physical damage to land by overbank deposition of sediment upon the flood plains of sample watersheds and main stem reaches of the San Antonio River was determined by reconnaissance and detailed survey investigations. The damage appraisers determined the average acreage damaged annually by damage classes and these estimates of present damage were used as a basis for estimating expected future damage.

On areas where overbank deposition of sediment occurs, the loss of net income on the area damaged annually was capitalized to determine the average annual damage. The following calculations are illustrative of the procedure used in determining sediment damage under present conditions:

Calaveras Creek Sample Watershed

1.70 acres damaged annually by 10 percent.

0.30 acres damaged annually by 15 percent.

3.04 acres damaged annually by 20 percent.

4.14 acres damaged annually by 25 percent.

1/ Paulson, W. E., "Efficiency as Applied to Cotton Ginning Business," Bull. 654, Texas Agricultural Experiment Station, College Station, Texas; and Billinger, Roy., "Financial Operations of a Group of Oklahoma Farmers Elevators 1930-32." Bull. 221, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.

\$7.19 = net value per acre of production after production costs, taxes and overhead were deducted.

10 percent of \$7.19 capitalized at 4 percent interest x 1.70 = \$30.56 net value of production loss on area damaged 10 percent.

15 percent of \$7.19 capitalized at 4 percent interest x 0.30 = \$8.08 net value of production loss on area damaged 15 percent.

20 percent of \$7.19 capitalized at 4 percent interest x 3.04 = \$109.29 net value of production loss on area damaged 20 percent.

25 percent of \$7.19 capitalized at 4 percent interest x 4.14 = \$186.04 net value of production loss on area damaged 25 percent.

\$30.56 + \$8.08 + \$109.29 + \$186.04 = \$334.

Crop and pasture damages were adjusted downward to avoid double counting of damage from loss of production in the future from overbank sediment deposition. Assuming that sediment deposition, occurring at a specified annual rate, will continue to accumulate over a period of 100 years, the annual damage is converted to the equivalent of 100 percent damage and divided by 2 to equal the average area damaged over the 100-year period. The ratio of acres damaged and the average annual acres inundated times the average annual crop and pasture damage will equal the amount to be deducted from annual crop and pasture damage. The following calculations are illustrative of the procedure used:

Sediment Damage to Land, Calaveras Creek Sample Watershed

Acres Damaged in 100 Years	Average Annual Percent Damage	Total Acres Damaged 100 Percent Equivalent
166	10	16.6
30	15	4.5
304	20	60.8
414	25	103.5
Total		185.4

185.4/2 = 92.7 average acres damaged the equivalent of 100 percent in 100 years.

1550 = average acres inundated annually.

\$4,491 = average annual crop and pasture damage with present conditions.

92.7/1550 x \$4,491 = \$268.

\$4,491 - \$268 = \$4,223 adjusted average annual crop and pasture damage.

The reduction in sedimentation damage which would result from the installation of phases of the recommended program was computed for each valley investigated. The reduction in area inundated annually with the phases of the recommended program in effect was used as the basis for estimating the reduction in annual sediment damages.

Reservoir Sedimentation Damage: The cost of Medina reservoir in the San Antonio River Watershed was adjusted from the original to 1950 prices by the ENR Index of construction costs. Damage due to sedimentation was calculated on the cost per acre foot of storage capacity. The method used is illustrated as follows:

1. Original storage capacity at spillway crest 274,065 acre-feet.

2. Estimated 1950 Cost of Construction - - - - - $9,558,802.

3. Cost per acre-foot - - - - - - - - - - - - - - $34.88.

4. Total annual depletion of storage capacity- - 255 acre-feet.

5. Annual damage, present conditions (4) x (3) - $8,894

Method of Determining Total Annual Floodwater and Sediment Damage

Application of Flood Occurrences to Per Acre Damage Rates: Per acre values of crop and other agricultural damages, as shown in table 27 and figure 31, were used in determining total annual agricultural flood damages. The acres flooded by depth-increments and by seasons were estimated from valley cross-sections in sample watersheds and in reaches of the main streams. Curves were then constructed to correlate the total acreages flooded with the runoff, and the total crop and pasture damage with the runoff, figures 32, 33, and 34, by seasons for each sample watershed and main stream reach.

The value of crop and pasture damage caused in the watersheds was calculated according to the season in which the flood occurred, as shown in table 29. The total value of this damage and the total area inundated were plotted opposite the inches of runoff causing the stage associated with the damage, as illustrated in figure 32. Similar curves were plotted showing the area inundated and the damage caused by runoff after installation of floodwater retarding structures, figure 35. Runoff-damage curves for other sample watersheds after installation of retarding structures are shown in figure 36.

The area flooded and the total crop and pasture damage for each flood in the series (1920-1944) were read directly from the curves for damages both under present conditions and in the future with various phases of the recommended program installed. The average annual damage was calculated by dividing the total damage by the 25 years in the period of record. A summary of crop and pasture damage for Calaveras Creek Sample Watershed is as follows:

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL DIRECTOR

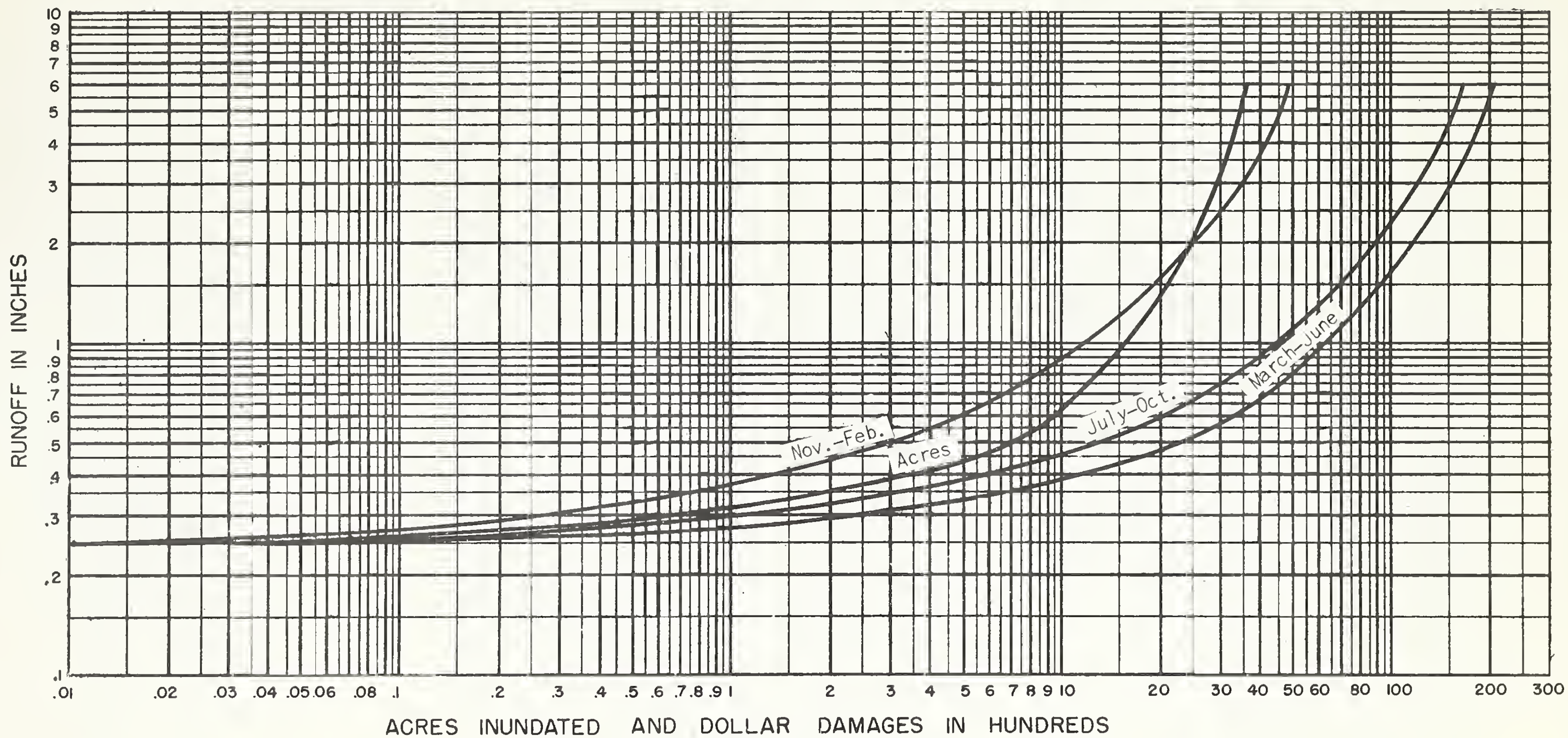

Figure 32

ACRES INUNDATED AND CROP & PASTURE DAMAGE
FOR VARIOUS AMOUNTS OF RUNOFF
WITHOUT FLOODWATER RETARDING STRUCTURES
CALAVERAS CREEK

SAN ANTONIO RIVER WATERSHED

TEXAS

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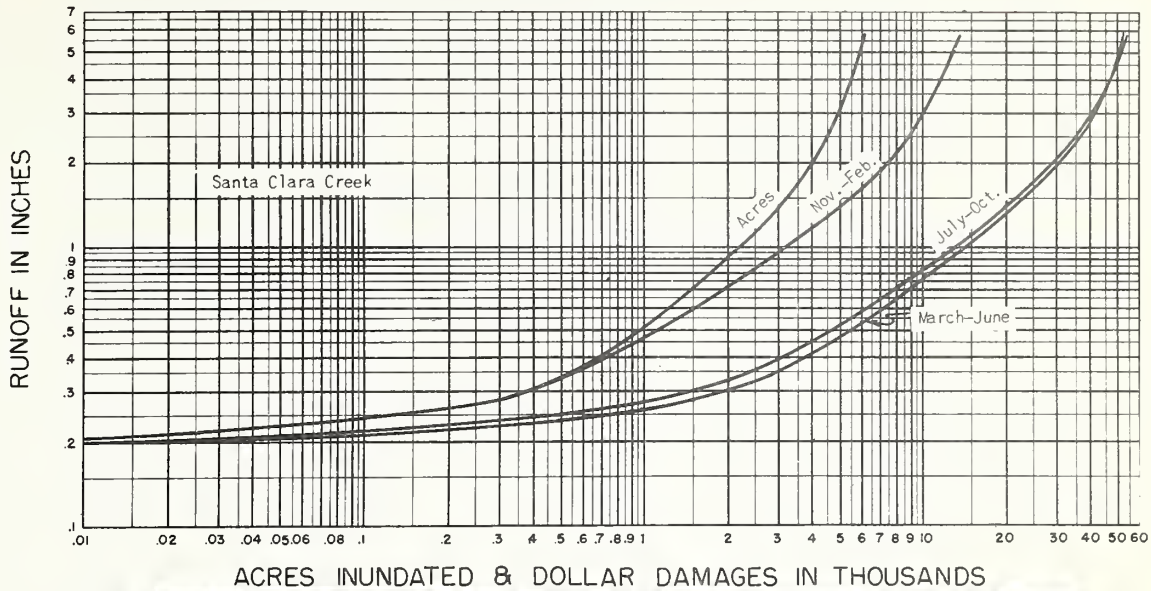

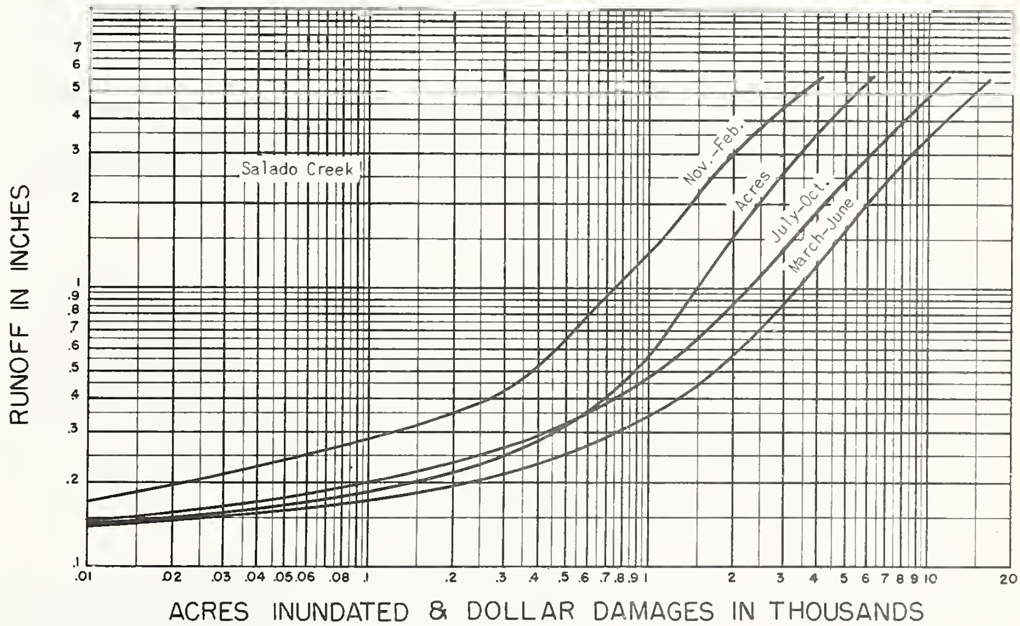

Figure 33

AREA INUNDATED AND CROP & PASTURE DAMAGE
FOR VARIOUS AMOUNTS OF RUNOFF
WITHOUT FLOODWATER RETARDING STRUCTURES
SAMPLE WATERSHEDS

SAN ANTONIO RIVER WATERSHED
TEXAS

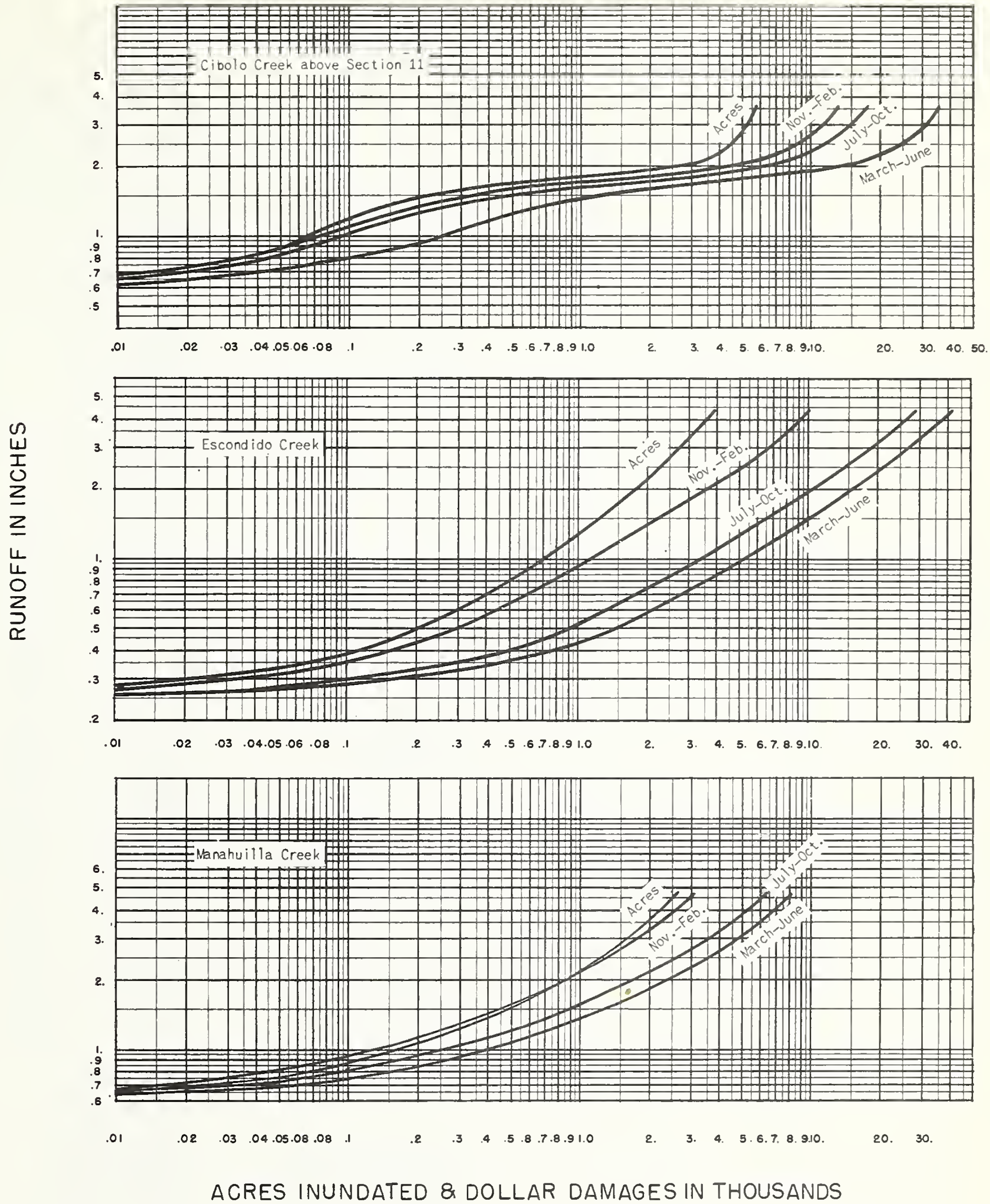

Figure 34

AREA INUNDATED AND CROP & PASTURE DAMAGE
FOR VARIOUS AMOUNTS OF RUNOFF
WITHOUT FLOODWATER RETARDING STRUCTURES
SAMPLE WATERSHEDS

SAN ANTONIO RIVER WATERSHED
TEXAS

Table 29. Runoff-Damage Relationship 1/
Calaveras Creek

San Antonio River Watershed, Texas

Season	Runoff 2/	Discharge at Control Section 3/	Area Flooded at Various Depths and Damage: 0' - 1.0'		1.1' - 3.0'		3' and above		Total Area	Total Damage
	(inches)	(c.f.s.)	(acres)	(dollars)	(acres)	(dollars)	(acres)	(dollars)	(acres)	(dollars)
July-October Damage Factor 4/	-	-	$1.64		$3.49		$5.15			
	0.25	2,455	43	71	3	10	0	0	46	81
	0.50	4,910	654	1,073	57	199	4	21	715	1,293
	1.00	9,820	599	982	943	3,291	38	196	1,580	4,469
	2.00	19,640	482	790	1,592	5,556	443	2,281	2,517	8,627
	4.00	39,300	295	484	830	2,897	2,063	10,624	3,188	14,005
	6.00	58,900	320	525	648	2,262	2,653	13,663	3,621	16,450
March - June Damage Factor 4/	-	-	$3.00		$4.42		$6.18			
	0.25			129		13		0		142
	0.50			1,962		252		25		2,239
	1.00	As above	As above	1,797	As above	4,168	As above	235	As above	6,200
	2.00			1,446		7,037		2,738		11,221
	4.00			885		3,669		12,749		17,303
	6.00			960		2,864		16,396		20,220
November-February Damage Factor 4/	-	-	$0.33		$1.01		$1.52			
	0.25			14		3		0		17
	0.50			216		58		6		280
	1.00	As above	As above	198	As above	952	As above	58	As above	1,208
	2.00			159		1,608		673		2,440
	4.00			97		838		3,136		4,071
	6.00			106		654		4,033		4,793

1/ Present condition in flood plain. 2/ Depth of runoff from the drainage area above valley section 1. 3/ Peak rate of discharge at valley section 1. 4/ Damage on 1 acre inundated for season and depth of flooding.

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DEPARTMENT OF AGRICULTURE

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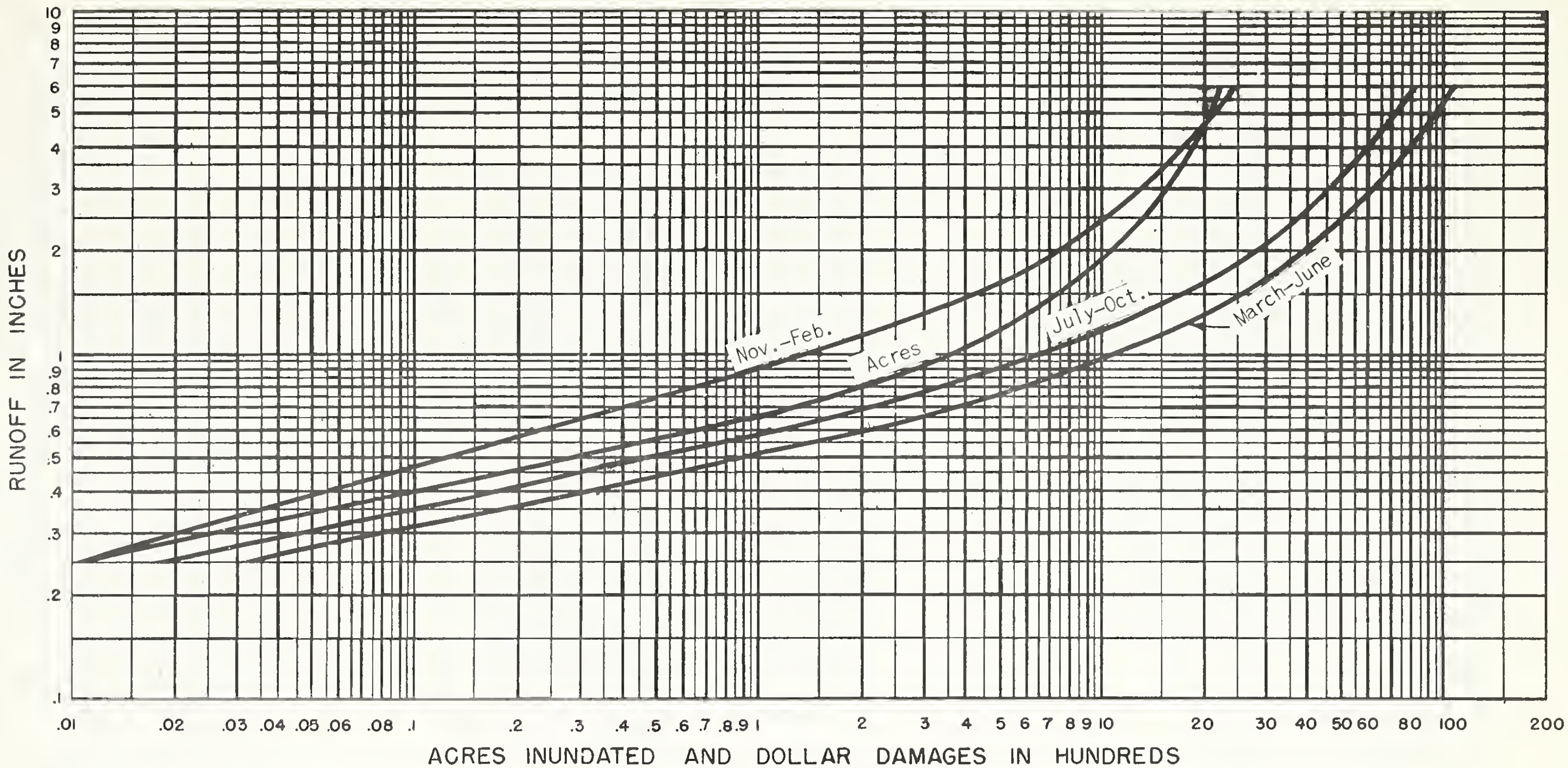
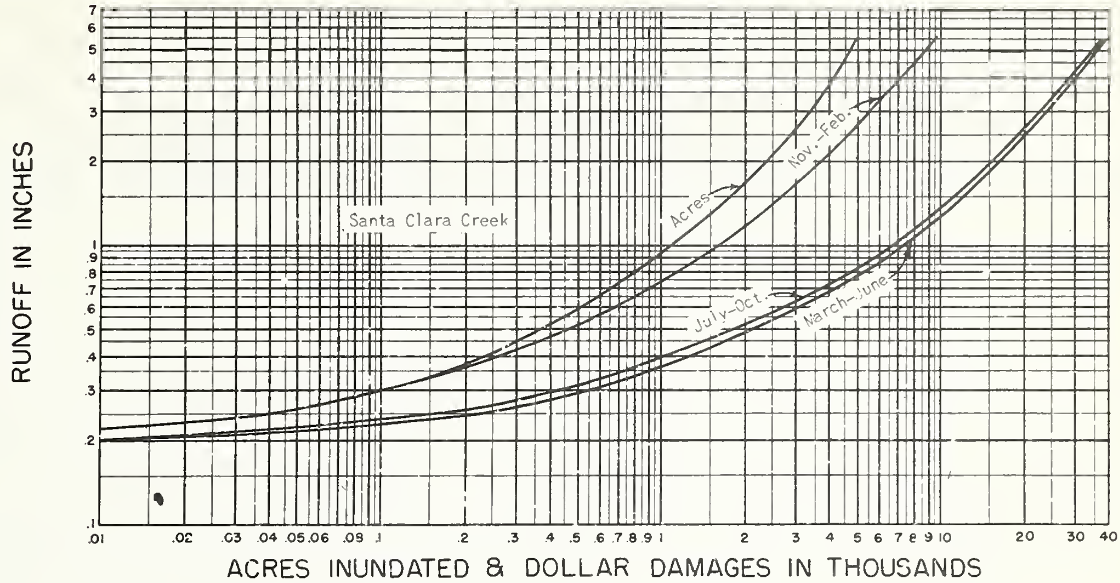


Figure 35

AREA INUNDATED AND CROP & PASTURE DAMAGE
FOR VARIOUS AMOUNTS OF RUNOFF
WITH FLOODWATER RETARDING STRUCTURES INSTALLED
(EXCLUDES POOL AREA OF STRUCTURES)
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

4-11-52 4-N-8222-27



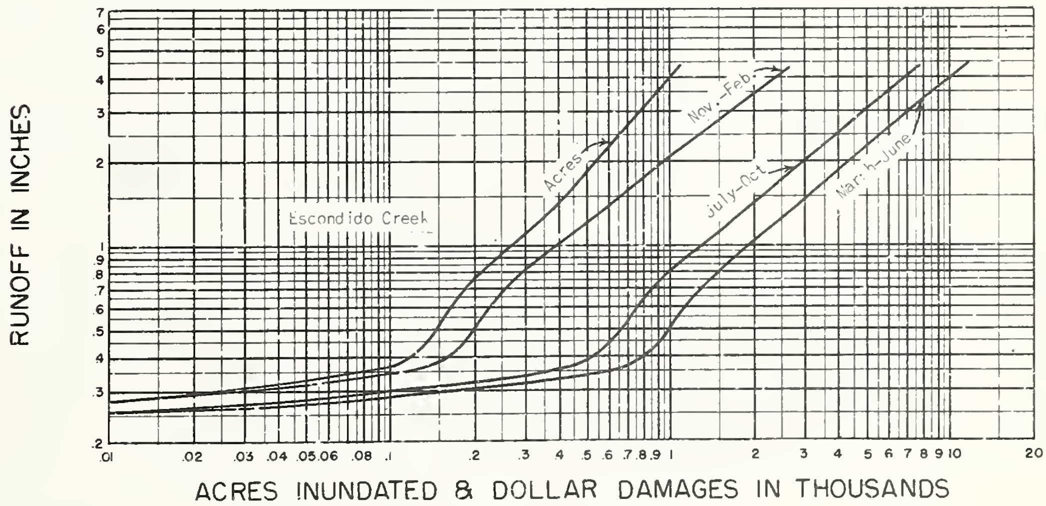


Figure 36

AREA INUNDATED AND CROP & PASTURE DAMAGE
FOR VARIOUS AMOUNTS OF RUNOFF
WITH FLOODWATER RETARDING STRUCTURES INSTALLED
(EXCLUDES POOL AREA OF STRUCTURES)
SAMPLE WATERSHEDS

SAN ANTONIO RIVER WATERSHED
TEXAS

	Under Present Conditions		With Land Treatment and Stabilizing Measures		With Land Treatment Measures and Floodwater Retarding Structures	
	Area Flooded	Damage	Area Flooded	Damage	Area Flooded	Damage
	(acres)	(dollars)	(acres)	(dollars)	(acres)	(dollars)
Total	38,696	112,275	25,046	75,025	4,649	12,875
Average Per Year	1,550	4,491	1,002	3,001	186	515

It was recognized that a series of floods in one crop year would have an effect on the damage to crops by preventing complete restoration of damageable values between floods, and certain floods were eliminated from the flood series for crop and pasture damage, (appendix III, calculation of flood occurrences and magnitudes). The revised series is shown in table 30. Further adjustment of crop and pasture damage was made to take into account the fact that often only partial restoration of damageable value is made prior to a succeeding flood.

In computing all other types of damages that had no particular relationship to seasons and frequency, all floods were retained in the period of record.

In calculating damages for flood plain scour, an index of flooding was used. The total acreage flooded during the 25-year flood series under present conditions was considered as 100 percent and the total acreages flooded under future conditions with each of the phases of the recommended program installed were expressed as percentages of present acreages. The present damage was then multiplied by these percentages to derive the damage under future treated conditions.

For example, the present average annual damage from scour on approximately 125 acres in the Calaveras Creek Sample Watershed was estimated at $2,365.

The total area flooded under present conditions from 1920 to 1944 (42,031 acres) equals 100 percent. The area flooded after installation of land treatment and stabilizing measures (26,240 acres) is 62.5 percent. The 4,692 acres flooded after installation of land treatment and stabilizing measures and floodwater retarding structures (flood prevention measures) is 11.2 percent. Therefore, estimated annual damage from flood plain scour is $1,478 after installation of land treatment and stabilizing measures and $265 after installation of land treatment and stabilizing measures and flood prevention measures. Indices of flooding on sample watersheds are tabulated in table 28.

Table 30 Damage-Producing Storms
Calaveras Creek, Bexar and Wilson Counties

San Antonio River Watershed, Texas

Date	Precipitation	Present Condition of Land Use			With Land Treatment Measures			With Recommended Program			With Floodwater Retarding Structures Only		
		Runoff	Area Flooded	Damage 1/	Runoff	Area Flooded	Damage 1/	Runoff	Area Flooded	Damage 1/	Runoff	Area Flooded	Damage 1/
	(inches)	(inches)	(acres)	(dollars)	(inches)	(acres)	(dollars)	(inches)	(acres)	(dollars)	(inches)	(acres)	(dollars)
May 15-16, 1920	2.64	0.46	540	1,840	0.34	157	530	0.34	5	15	0.46	19	61
March 1-2, 1921	2.74	0.48	620	2,070	0.37	232	820	0.37	7	21	0.48	24	74
April 5-7, 1921	2.59	0.44	470	1,625	0.33	130	445	0.33	4	12	0.44	16	50
September 8-9, 1921	5.97	1.68	2,260	7,450	1.47	2,080	6,600	1.47	715	1,750	1.68	855	2,220
April 3-4, 1922	2.30	0.36	205	720	0.26	6	24	0.26	1	3	0.36	6	18
April 26-27, 1922	2.05	0.28	28	87	0.20	-	-	0.20	-	-	0.28	2	6
February 21-22, 1923	3.80	0.83	1,350	880	0.68	1,087	600	0.68	120	37	0.83	222	76
March 26-27, 1923	3.17	0.62	968	3,500	0.49	652	2,180	0.49	27	92	0.62	83	232
August 27-28, 1923	3.07	0.58	885	1,840	0.45	510	930	0.45	17	31	0.58	62	98
October 14, 1923	2.10	0.29	44	72	0.21	-	-	0.21	-	-	0.29	2	4
November 13-14, 1923	2.37	0.37	232	95	0.27	13	5	0.27	2	1	0.37	7	4
June 21-22, 1924	3.36	0.68	1,087	4,030	0.53	762	2,600	0.53	40	115	0.68	120	330
May 8-10, 1925	2.42	0.38	264	930	0.28	28	87	0.28	2	6	0.38	8	24
April 20-21, 1926	3.05	0.58	385	3,100	0.45	510	1,730	0.45	17	56	0.58	62	173
April 11-13, 1927	2.05	0.28	28	87	0.20	-	-	0.20	-	-	0.28	2	6
June 13-14, 1927	3.21	0.63	982	3,580	0.49	652	2,180	0.49	27	92	0.63	89	247
May 13-14, 1928	2.39	0.38	264	930	0.28	28	87	0.28	2	6	0.38	8	24
June 2-3, 1928	3.13	0.61	950	3,410	0.48	620	2,070	0.48	24	74	0.61	78	218
September 21-22, 1928	2.45	0.39	295	510	0.29	44	72	0.29	2	4	0.39	9	15
November 5-6, 1928	2.49	0.41	362	143	0.30	64	26	0.30	3	2	0.41	11	6
May 24-25, 1929	2.18	0.32	103	370	0.23	-	-	0.23	-	-	0.32	3	11
June 28-29, 1929	2.64	0.46	540	1,840	0.34	157	530	0.34	5	15	0.46	19	61
June 12, 1930	2.32	0.36	205	720	0.26	6	24	0.26	1	3	0.36	6	18
January 14-16, 1931	2.30	0.36	205	84	0.26	6	2	0.26	1	-	0.36	6	4
June 26-29, 1931	3.39	0.69	1,105	4,115	0.54	787	2,700	0.54	44	124	0.69	126	347
July 17-18, 1931	2.34	0.37	232	390	0.27	13	22	0.27	2	3	0.37	7	12
January 3-4, 1932	2.05	0.28	28	9	0.20	-	-	0.20	-	-	0.28	2	1
September 22-24, 1932	4.59	1.12	1,740	5,000	0.94	1,510	4,160	0.94	306	550	1.12	460	900
May 25-26, 1933	2.71	0.48	620	2,070	0.37	232	820	0.37	7	21	0.48	24	74
July 30-31, 1933	2.58	0.43	435	790	0.32	103	155	0.32	3	6	0.43	14	25
April 4-6, 1934	2.54	0.42	400	1,360	0.31	80	300	0.31	3	9	0.42	12	39
July 25-26, 1934	2.85	0.52	707	1,420	0.40	325	580	0.40	10	17	0.52	37	62
December 26-27, 1934	2.57	0.43	435	177	0.32	103	42	0.32	3	2	0.43	14	7
May 9, 1935	3.75	0.82	1,330	5,070	0.67	1,067	3,935	0.67	113	314	0.82	214	625
June 9-16, 1935	7.37	2.32	2,615	12,650	2.07	2,400	11,400	2.07	1,070	4,100	2.32	1,180	4,700
September 23-25, 1935	2.55	0.43	435	790	0.32	103	155	0.32	3	6	0.43	14	25
March 2, 1936	2.46	0.40	325	1,140	0.30	64	240	0.30	3	8	0.40	10	31
June 27-30, 1936	4.49	1.08	1,690	6,700	0.91	1,470	5,670	0.91	285	855	1.08	430	1,340
August 30-31, 1936	2.26	0.34	157	240	0.25	-	-	0.25	-	-	0.34	5	8
May 31, 1937	3.97	0.83	1,430	5,500	0.72	1,160	4,320	0.72	144	365	0.88	263	790
December 14-15, 1937	3.71	0.79	1,280	808	0.64	1,005	526	0.64	95	29	0.79	193	64
May 15-16, 1938	2.15	0.32	103	370	0.23	-	-	0.23	-	-	0.32	3	11
May 30, 1939	2.71	0.47	580	1,960	0.36	205	720	0.36	6	18	0.47	22	67
July 11-12, 1939	2.11	0.30	64	95	0.22	-	-	0.22	-	-	0.30	3	4
June 29-30, 1940	3.48	0.72	1,160	4,320	0.58	885	3,100	0.58	62	173	0.72	144	365
January 27-28, 1941	2.38	0.38	264	105	0.28	28	9	0.28	2	1	0.38	8	4
March 17-18, 1941	2.09	0.29	44	180	0.21	-	-	0.21	-	-	0.29	2	7
April 26-27, 1941	3.47	0.72	1,160	4,320	0.58	885	3,100	0.58	62	173	0.72	144	365
September 16-17, 1941	3.20	0.63	982	2,190	0.49	652	1,200	0.49	27	47	0.63	89	136
April 6-7, 1942	2.58	0.43	435	1,500	0.32	103	370	0.32	3	11	0.43	14	44
July 4-6, 1942	8.48	2.86	2,840	11,600	2.58	2,730	10,650	2.58	1,285	3,770	2.86	1,410	4,220
October 4-6, 1942	3.59	0.76	1,235	3,050	0.61	950	2,055	0.61	78	120	0.76	173	275
July 11-13, 1943	2.69	0.47	583	1,050	0.36	205	340	0.36	6	11	0.47	22	38
May 27-28, 1944	2.62	0.45	510	1,730	0.34	157	530	0.34	5	15	0.45	17	56

1/ Crop and Pasture Damage only.
- Insufficient runoff to produce flooding.

Other agricultural damages were calculated by applying the per acre damage factors, figure 31, to the acreage inundated by each flood in the flood series. The total damage sustained was divided by the number of years in the series (25) to determine the average annual damage. This is illustrated in table 31.

Road and bridge damage was calculated by use of percentage of flood plain inundated-damage curves, figure 31. The damage rate for each damage-producing flood was read from the curve and applied to the acreage inundated to arrive at the damage from that flood, table 32. The curves for the various sample watersheds differed in the point where damage began, in the slope of the curve, and in maximum damage rate, but they were similar in general shape and characteristics.

Damage to urban communities and industrial installations was calculated directly in the areas concerned.

Average annual damages for each sample watershed were summarized by types of damage (other than urban, industrial and reservoir sedimentation) for present conditions and with only the land treatment measures installed, table 33. These data were then expanded to the entire creek watershed in the ratio of drainage area in the sample watershed to the area in the entire creek watershed represented by that sample. Reductions in damages after installation of floodwater retarding structures were not always expanded on the same areal base, as they were dependent on the amounts of these flood prevention measures installed. Table 34 illustrates this procedure for the creek watershed.

A summary of all floodwater and sediment damages by creek watersheds for the San Antonio River Watershed is shown in table 35.

Main Stem Flood Damages

The acres in each flood depth increment, as explained in appendix III, were multiplied by a seasonal crop and pasture damage value. The sum of the damages of all depth increments for each routed flood was plotted against the corresponding peak discharge. Four curves for each of the four major reaches were developed from the above calculations, which show the area inundated versus peak discharge, and three seasonal damage curves were constructed similar to figure 29, appendix III. Table 29 illustrates the method by which the damage values for various size floods were determined.

The area inundated and the corresponding crop and pasture damage for each flood in the series was determined for present conditions from the routing of these floods and with the use of the damage curves developed for each of the 4 major reaches. Pertinent data regarding the flood series is shown in table 36. The area inundated and crop and pasture damages after the application of a complete land treatment program on the watershed was evaluated by applying the expected reductions to the peak

Table 31. Other Agricultural Damages by Recorded Floods, 1920-1944 Flood Series, Calaveras Creek Sample Watershed

San Antonio River Watershed, Texas

Date of Storm	Under Present Conditions			With Land Treatment and Stabilizing Measures			With Land Treatment and Stabilizing Measures and Floodwater Retarding Structures		
	Area Flooded (acres)	Damage Per Acre (dollars)	Total Damage (dollars)	Area Flooded (acres)	Damage Per Acre (dollars)	Total Damage (dollars)	Area Flooded (acres)	Damage Per Acre (dollars)	Total Damage (dollars)
May 13-16, 1920	540	1.89	1,020	157	0.67	105	5	-	-
March 1-2, 1921	620	2.18	1,350	232	0.95	220	7	-	-
April 5-7, 1921	470	1.70	800	130	0.58	76	4	-	-
Sept. 8-9, 1921	2,260	8.63	19,500	2,080	7.69	16,000	715	2.52	1,800
April 3-4, 1922	205	0.85	175	6	-	-	1	-	-
* * *	* *	* *	* *	* *	* *	* *	* *	* *	* *
April 6-7, 1942	435	1.56	680	103	0.50	51	3	-	-
July 4-6, 1942	2,840	11.97	34,000	2,730	11.36	31,000	1,285	4.36	5,600
Oct. 4-6, 1942	1,235	4.21	5,200	950	3.26	3,100	78	0.40	31
July 11-13, 1943	583	2.10	1,225	205	0.85	175	6	-	-
May 27-28, 1944	510	1.84	940	157	0.67	105	5	-	-
Total	38,745		186,255	25,046		126,745	4,649		12,227
Average Per Year	1,550		7,450	1,002		5,070	186		489

*** Recorded Floods omitted from table but considered in "total" and "average per year" results.

Table 32. Damage to Roads, Bridges and Railroads by Recorded Floods 1920-1944 Flood Series, Calaveras Creek Sample Watershed

San Antonio River Watershed, Texas

Date of Storm	Under Present Conditions			With Land Treatment and Stabilizing Measures			With Land Treatment and Stabilizing Measures and Floodwater Retarding Structures		
	Area Flooded	Damage Per Acre	Total Damage	Area Flooded	Damage Per Acre	Total Damage	Area Flooded	Damage Per Acre	Total Damage
	(acres)	(dollars)	(dollars)	(acres)	(dollars)	(dollars)	(acres)	(dollars)	(dollars)
May 13-16, 1920	540	0.26	140	157	-	-	5	-	-
March 1-2, 1921	620	0.34	210	232	0.06	14	7	-	-
April 5-7, 1921	470	0.20	96	130	-	-	4	-	-
Sept. 8-9, 1921	2,260	4.87	11,000	2,080	3.85	8,000	715	0.44	315
April 3-4, 1922	205	0.05	10	6	-	-	1	-	-
* * *	* *	* *	* *	* *	* *	* *	* *	*	
April 6-7, 1942	435	0.18	77	103	-	-	3	-	-
July 4-6, 1942	2,840	9.15	26,000	2,730	8.06	22,000	1,285	1.32	1,700
Oct. 4-6, 1942	1,235	1.30	1,600	950	0.74	700	78	-	-
July 11-13, 1943	583	0.32	185	205	0.05	10	6	-	-
May 27-28, 1944	510	0.25	125	157	-	-	5	-	-
Total			86,868			58,778			3,034
Average Annual			3,475			2,351			121

*** Recorded floods omitted from table but considered in "total" and "average per year" results.

Table 33. Summary of Floodwater and Sediment Damages Under Present Conditions and After Installation of Phases of the Recommended Program 1/
Calaveras Creek Sample Watershed

San Antonio River Watershed, Texas

Type of Damage	Average Annual Damage			
	Under Present Conditions	With Land Treatment and Stabilizing Measures Installed 2/	With Land Treatment Measures and Floodwater Retarding Structures	With Floodwater Retarding Structures Only 3/
	(dollars)	(dollars)	(dollars)	(dollars)
Floodwater Damage				
Crops and Pasture	4,223	2,822	484	682
Flood Plain Scour	2,365	1,478	265	390
Other Agricultural	7,450	5,070	489	684
Nonagricultural	3,475	2,351	121	182
Subtotal	17,513	11,721	1,359	1,938
Sediment Damage				
Valley Sediment Deposition	334	209	37	55
Subtotal	334	209	37	55
Indirect Damage	2,052	1,372	161	229
Total Average Annual Damage	19,899	13,302	1,557	2,222

1/ 1950 prices.
2/ With the going program and the land treatment and stabilizing measures of the program installed.
3/ With present conditions and floodwater retarding structures installed.

Table 34. Summary of Floodwater and Sediment Damage Under Present Conditions and After Installation of Phases of the Recommended Program, Lower Medina River Watershed 1/

San Antonio River Watershed, Texas

Portion of Creek Watershed and Type of Damage	Area Expansion Factor, Land Treatment and Stabilizing Measures 2/	Area Expansion Factor, Floodwater Retarding Structures 3/	Under Present Conditions (dollars)	With Land Treatment and Stabilizing Measures Installed 4/ (dollars)	With Land Treatment Measures and Floodwater Retarding Structures (dollars)	With Floodwater Retarding Structures Only 5/ (dollars)
Area similar to:						
Calaveras Creek	1.4688	0.9688				
Crops and Pasture			6,203	4,145	1,880	2,773
Flood Plain Scour			3,474	2,171	996	1,560
Other Agricultural			10,942	7,447	3,009	4,388
Nonagricultural			5,104	3,453	1,293	1,914
Valley Sediment			491	307	140	220
Indirect			3,014	2,015	842	1,248
Total			29,228	19,538	8,160	12,103
Salado Creek	1.8640	0				
Crops and Pasture			6,050	4,882	4,882	6,050
Flood Plain Scour			2,004	1,594	1,594	2,004
Other Agricultural			10,256	8,045	8,045	10,256
Nonagricultural			12,688	9,827	9,827	12,688
Valley Sediment			306	242	242	306
Indirect			3,756	2,951	2,951	3,756
Total			35,060	27,541	27,541	35,060
Cibolo Creek	0.4291	0				
Crops and Pasture			1,084	997	997	1,084
Flood Plain Scour			139	128	128	139
Streambank Erosion			54	54	54	54
Other Agricultural			987	912	912	987
Nonagricultural			430	381	381	430
Valley Sediment			-	-	-	-
Indirect			270	247	247	270
Total			2,964	2,719	2,719	2,964
Lower Medina River Watershed Total						
Crops and Pasture			13,337	10,024	7,759	9,907
Flood Plain Scour			5,617	3,893	2,718	3,703
Streambank Erosion			54	54	54	54
Other Agricultural			22,185	16,404	11,966	15,631
Nonagricultural			18,222	13,661	11,501	15,032
Valley Sediment			797	549	382	526
Indirect			7,040	5,213	4,040	5,274
Grand Total			67,252	49,798	38,420	50,127

1/ 1950 prices.
2/ Expansion factor for land treatment and stabilizing measures only.
3/ Expansion factor for floodwater retarding structures, no structures are recommended for Salado and Cibolo Creek Sample Watersheds at this time.
4/ With the going program and the land treatment and stabilizing measures of the recommended program installed.
5/ With present conditions and floodwater retarding structures installed.

Table 35. Average Annual Flood Damages, by Creek Watersheds 1/, 1950 Prices

San Antonio River Watershed, Texas

Creek Watershed	Under Present Conditions (dollars)	With Land Treatment and Stabilizing Measures Installed 2/ (dollars)	With Land Treatment Measures and Floodwater Retarding Structures (dollars)	With Floodwater Retarding Structures Only 3/ (dollars)
Upper San Antonio	131,919	99,686	56,114	73,304
Lower San Antonio	67,381	57,006	35,555	42,364
Upper Medina	25,068	21,730	21,730 4/	25,068 4/
Lower Medina	67,252	49,798	38,420	50,127
Upper Cibolo	6,907	6,336	6,336 4/	6,907 4/
Lower Cibolo	252,537	184,844	94,097	125,315
Ecleto	39,214	33,464	16,860	19,848
GRAND TOTAL	590,278	452,864	269,112	342,933

1/ Does not include main stem damages on the Lower Cibolo Creek or San Antonio River.

2/ Includes the going program and the land treatment and stabilizing measures of the recommended program.

3/ With present conditions and floodwater retarding structures installed.

4/ Floodwater retarding structures not recommended at this time.

Table 36. Damage Producing Storms on the San Antonio River 1/
September 1924 - September, 1949, 25 Years

San Antonio River Watershed, Texas

Date of Storm	Present Condition of Land Use				With Land Treatment and Stabilizing Measures			With Recommended Program		
	Reaches Flooded	Peak Discharge (c.f.s.)	Area Inundated (acres)	Damage 2/ (dollars)	Peak Discharge (c.f.s.)	Area Inundated (acres)	Damage 2/ (dollars)	Peak Discharge (c.f.s.)	Area Inundated (acres)	Damage 2/ (dollars)
October 15, 1925	1	7,310	4,500	10,100	6,000	900	2,400	6,000	900	2,400
April 23, 1926	1, 2	18,000	16,700	79,800	15,500	12,450	50,700	15,100	12,350	50,200
January 11, 1929	1, 2	20,000	21,190	26,075	17,400	15,150	16,300	16,695	14,750	15,300
May 29, 1929	1, 4	12,700	1,600	9,300	10,300	0	0	10,200	0	0
June 15, 1935	1, 2, 4	42,900	58,480	637,400	39,100	54,400	546,000	34,880	50,030	465,400
July 3, 1936	1, 2, 4	32,400	45,850	326,700	29,300	41,380	280,100	26,670	38,150	224,400
June 2, 1937	1, 2, 4	29,600	42,090	381,800	26,300	36,490	297,500	24,155	32,120	226,100
July 2, 1940	1, 2	17,800	18,000	56,400	15,000	12,000	33,900	14,685	11,850	33,300
November 6, 1940	1, 2	16,200	13,100	14,300	14,000	9,550	8,950	13,845	9,500	8,900
May 1, 1941	1, 2	22,000	27,500	161,500	20,300	22,900	132,600	19,545	21,700	115,600
July 14, 1941	1, 2	12,700	7,320	18,800	10,700	3,400	8,200	10,700	3,400	8,200
July 6, 1942	1, 2, 4	52,100	61,890	581,400	47,800	60,080	542,500	42,170	56,540	468,100
May 28, 1944	1, 2	15,000	11,900	47,600	13,000	7,500	28,400	13,000	7,500	28,400
September 1, 1944	1	6,590	2,400	6,400	5,400	0	0	5,300	0	0
May 19, 1946	1, 2	12,700	7,370	26,000	10,800	3,600	11,000	10,800	3,600	11,000
September 29, 1946	1,2,3,4	60,000	90,065	955,958	56,500	87,800	921,000	51,205	83,210	835,300
August 26, 1948	1, 2, 4	20,000	16,540	85,700	16,800	9,350	33,900	16,195	9,050	30,600
April 25, 1949	1, 2	20,800	24,000	134,800	18,800	18,200	98,100	17,870	17,150	77,100
June 28, 1949	1, 2, 4	19,500	16,650	130,300	17,500	10,200	70,400	16,260	9,750	62,900

1/ Main stem reaches 1 - 4, mouth to city of San Antonio.
2/ Crop and pasture damage only.

discharges along the main stem reaches. Having established the relationship between peak discharge and damages, the resultant damages were determined by routing each storm and using the same discharge-damage curves as under present conditions.

A summary of all floodwater and sediment damages for the main stem reaches of the watershed is shown in table 37. This table also includes a watershed total of average annual flood damages on valley land.

DESCRIPTION OF PHYSICAL SEDIMENTATION DAMAGES

Valley Sedimentation and Scour

Sediment and scour damages on the flood plain of the San Antonio River and most of its tributary valleys are relatively minor. The following is a brief discussion of the nature and amount of sediment, scour and related damages within each of the sample watersheds investigated. Data obtained within these samples, shown in table 38, were expanded to creek watersheds. Estimated net sediment contribution rates are shown for various sizes of watersheds in figure 37.

Upper Cibolo Creek: Sediment damages and sediment output rates in this watershed are considered as representative of the Edwards Plateau region. The chief type of damaging sediments is gravel, which forms bars in the channels and is occasionally deposited overbank. The upstream portions of the channels are filled with these gravels. Damages by accelerated overbank deposition are negligible. Scour channels have caused a 25 percent damage to 53 acres and a 10 percent damage to 392 acres. It is estimated that 0.6 of one acre is destroyed annually by bank erosion. Rates of sediment output in this sample watershed and in the area to which it applies are the lowest in the San Antonio River Watershed.

Salado Creek: This watershed comprises parts of three physiographic areas; the Edwards Plateau, Black Prairie and South Texas Coastal Plain. It is considered representative of several creeks which drain a wide belt consisting of parts of these areas. The coarser sediments, dominantly gravels, which are produced in the Edwards Plateau section, are carried by the stream and dropped as it enters the Black Prairie section. Numerous overbank gravel deposits are found in the latter area. Sediments carried by the stream and deposited below this point are fine textured and damages to the flood plain are negligible. A total of 243 acres has suffered damage by overbank deposits. These deposits consist largely of gravels which have caused a damage of 25 percent to 153 acres and 50 percent to 95 acres.

Damages by scour are significant. Approximately 25 percent of the flood plain of Salado Creek and its tributaries have been damaged by this process. The damage ranges from 10 to 90 percent. Damage due to bank erosion is negligible.

Table 37. Average Annual Flood Damages, Main Stem and Tributary Reaches, 1950 Prices

San Antonio River Watershed, Texas

Main Stem and Tributary Reaches	Average Annual Floodwater and Sedimentation Damage			
	Under Present Conditions	With Land Treatment and Stabilizing Measures Installed	With Land Treatment Measures and Floodwater Retarding Structures	With Floodwater Retarding Structures Only
	(dollars)	(dollars)	(dollars)	(dollars)
Lower Cibolo	19,270	11,924	5,678	7,271
San Antonio				
Reach 1	59,735	49,391	48,552	58,847
Reach 2	181,903	150,466	127,765	156,871
Reach 3	24,454	23,036	19,944	21,784
Reach 4	93,758	84,145	76,870	84,333
Main Stem Total	379,120	318,962	278,809	329,106
Creek Watershed Total	590,278	452,864	269,112	342,933
Grand Total	969,398	771,826	547,921	672,039

Table 38. Annual Weighted Damage to Flood Plains by Sedimentation, Scour and Stream Bank Erosion in Sample Watersheds, Creek Watersheds, and Sections of the Main Stem

San Antonio River Watershed, Texas

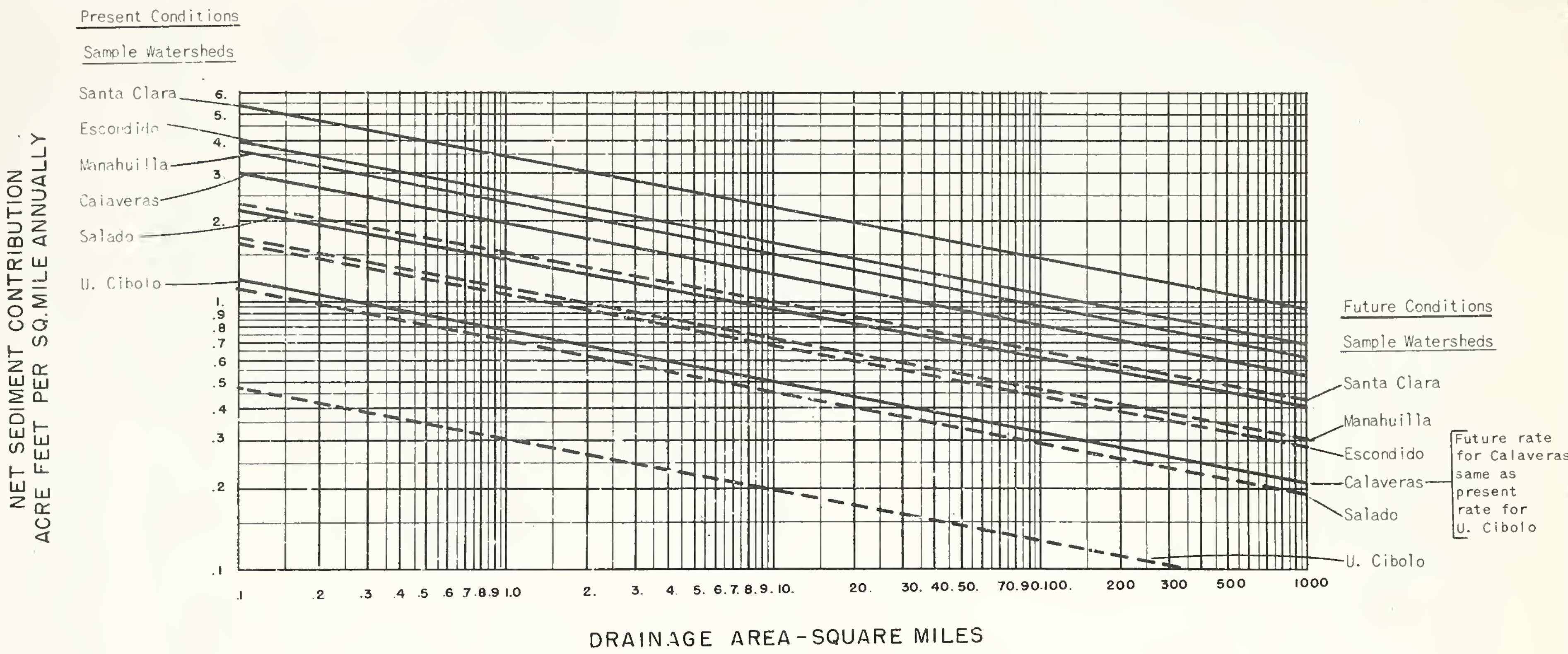
Name of Creek or Section of Watershed	Physiographic Section and Geologic Groups	Annual Damage by Sediment Deposition		Annual Damage by Flood Plain Scour		Annual Damage by Stream Bank Erosion	
		(acres)	(percent 1/)	(acres)	(percent 1/)	(acres)	(percent 1/)
Calaveras Creek	South Texas Coastal Plain; Midway-Wilcox	9	20	125	30	0.27	100
Salado Creek	Black Prairie, Edwards Plateau and South Texas Coastal Plain; Trinity-Austin-Taylor-Navarro-Midway-Wilcox	5	34	116	28	N 2/	
Santa Clara Creek	Black Prairie; Taylor-Navarro	3	10	157	20	N 2/	
Escondido Creek	South Texas Coastal Plain; Oakville-Catahoula	9	23	157	26	0.44	100
Manahuilla Creek	South Texas Coastal Plain; Lagarto-Goliad	27	25	110	25	3.17	100
Cibolo Creek	Edwards Plateau, South Texas Coastal Plain, Black Prairie. Most formations in above sections	16	14	306	19	2.04	100
Main Stem of the San Antonio River	All South Texas Coastal Plain	168	14	1,853	21	1.2	100

1/ Percent damage is the weighted average damage to the acres affected.
2/ N - Negligible.

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL DIRECTOR



LEGEND

——— Present conditions

– – – – Future Conditions or with complete land treatment

Figure 37

ESTIMATED NET SEDIMENT CONTRIBUTION RATES

SAN ANTONIO RIVER WATERSHED
TEXAS

4/23/52 4-R-8222-38

Calaveras Creek: Sediment and related damages which occur in this watershed are typical of the older formations of the South Texas Coastal Plain. Sheet and gully erosion have been active over much of the watershed and have produced moderately large amounts of sediment. Sediment production rates are not so high at present, due to the retirement of many areas from cultivation. Channel filling by sediments has often resulted in increased frequency and depth of flooding. Although most of the flood plain on Calaveras Creek and its tributaries receives substantial amounts of sediment deposition, only 10 percent of the total flood plain area is considered damaged by this process. This is due to the fine texture of most of the sediment and the fact that only a few inches are deposited during each flood. Parita Creek has the highest proportion of damage and one-third of its flood plain has suffered a productivity loss of 25 percent due to harmful sediment. Rates of damage on Calaveras, Chopaderas and other tributaries range from 10 to 25 percent.

Flood plain scour is a major item of damage. Over 25 percent of the total flood plain area has been scoured by floodwater, with resulting rates of damage ranging from 10 to 75 percent. Heaviest rates of damage are caused by deep scour channels, but larger areas are affected by sheet scour, a process in which a freshly plowed field may lose all soil down to plow depth during a flood.

Santa Clara Creek: This watershed was selected as being representative of all watersheds occurring entirely within the Black Prairie physiographic area. Rates of sediment output range from 2 to 6 acre feet per square mile of drainage area. Moderate to severe sheet erosion on the cultivated areas is the major source of sediment and it is estimated that 80 percent of the sediment transported is derived from sheet erosion. The remaining 20 percent is derived from gully, roadside and stream bank erosion. Although much sediment is deposited in the stream valleys, reduction of productivity is minor, as the sediments differ little in texture and fertility from the original flood plain soil. Only 173 acres, about 3 percent of the total flood plain area in Santa Clara Creek and its tributaries, were considered to be damaged. Productive capacity has been reduced about 10 percent on these acres, which occur immediately adjacent to the channel and have received the coarser sediments.

One of the greatest damages resulting from deposition is the smothering of pasture and growing crops. This has been included in crop and pasture floodwater damage due to the difficulty of separate evaluation.

Channel filling is occurring in the central portion of Santa Clara Creek and causes increased flooding. The entire acreage estimated to be damaged by sediment deposition occurs within the central reaches of the creek.

Flood plain scour has caused substantial damage to the flood plain of Santa Clara Creek and its tributaries. Approximately 25 percent of the total flood plain area has been damaged by scour channels and sheet

scour. The rate of damage ranges from 10 to 50 percent. The weighted average annual damage is 20 percent on 157 acres.

Escondido Creek: This watershed is representative of upper South Texas Coastal Plain formations occurring in the lower portion of the San Antonio River basin. Cultivation is the dominant land use and sheet erosion from cultivated lands is the major sediment source.

Sediment output is high but damages resulting from overbank deposition are low since the soils of the watershed are dominantly fine textured. Only about 11 percent of the total flood plain is estimated to be damaged by sediment deposits. Reduction in fertility on this acreage ranges from 10 to 50 percent, the average weighted damage being approximately 23 percent. Sediment production rates will be reduced an estimated 59 percent under a complete land treatment program.

Frequent flooding has caused substantial damage by scour to 40 percent of the flood plain. The decrease in fertility on the scoured areas ranges from 10 to 90 percent. The average weighted damage to 1,570 acres is 26 percent.

Manahuilla Creek: This creek is typical of several watersheds within the more sandy Tertiary formations in the lower reaches of the San Antonio River.

Accelerated deposition of sandy sediment has occurred on the flood plains of most of the streams in the area. Approximately 1,350 acres, or 52 percent, of the total flood plain of Manahuilla Creek has suffered damage from such deposits. The damage ranges from 10 to 75 percent, the weighted average damage being 27 percent.

Scour has caused damage of from 10 to 50 percent on 1,100 acres of the flood plain. Scour channels occurring in areas previously damaged by sediment deposition were not included in the damage appraisal.

Many of the small channels have suffered substantial capacity loss due to channel filling, while coarse sand and gravel have caused a capacity loss to the channel of Manahuilla Creek ranging from an estimated 20 percent in the upper reaches to 50 percent in the lower reaches. More than 3 acres are destroyed annually by bank erosion on Manahuilla Creek and its tributaries.

Rates of sediment contribution range from 1.5 to 2.5 acre-feet per square mile of drainage area under present conditions. Under complete land treatment these rates are expected to be reduced by slightly more than 50 percent.

Cibolo Creek: Damages by sediment deposition and flood plain scour on this creek are of moderate significance. Overbank flooding seldom occurs and is usually confined to the low-lying bottom adjacent to the

channel. The high alluvial terraces are flooded very infrequently. A total of 950 acres have been damaged by deposition of relatively coarse sediment. Approximately 10 acres are damaged 10 percent annually and 6 acres suffer 20 percent damage each year.

Scour has caused damage to approximately one-half of the flood plain area, but most of the damage does not exceed 10 percent. Stream bank erosion is insignificant, less than 2 acres being lost annually by this process.

Main Stem of the San Antonio River: Damaging sediment has been deposited on 11 percent of the total flood plain area along the San Antonio River. A total of 5,642 acres has suffered 10 percent damage and 4,451 acres have been damaged an estimated 20 percent. Most of the sediment is fine textured and the flood plain receiving such deposits is not considered to be damaged.

Scour has caused damage to 18,530 acres or approximately 20 percent of the total flood plain. Sheet scour and shallow scour channels cause damage ranging from 10 to 25 percent, while deep scour channels result in damages of 25 to 50 percent. The river banks are well stabilized and the loss of land by bank erosion is very minor.

Table 38 gives a summary of damages to sample watershed flood plains by sediment, scour and bank erosion.

Reservoir Sedimentation

Medina Lake is the only major reservoir in the San Antonio River Watershed. Other existing reservoirs are used primarily for recreation, although a few small lakes are used or were formerly used for irrigation.

Sedimentation conditions were investigated in the Mitchell, Blue Wing, Cassim, Elmendorf and Woodlawn Lakes, all located in Bexar County. Rates of sediment contribution to these reservoirs have been quite low and their average annual rates of capacity loss are estimated to be less than one-half of one percent. No attempt was made to evaluate monetary damage to these reservoirs due to the scarcity of original cost data.

The rate of capacity loss in Medina Lake is very low, since it is located in the low sediment producing Edwards Plateau. The following tabulation is a summary of the detailed survey (1948) for Medina Lake.

Sedimentation Data on Medina Lake

	Quantity	Unit
Age: 1/ -	35.2	Years
Watershed Area:		
Including lake area - - - - - - - - - - - -	633	Sq. Mi.
Excluding lake area - - - - - - - - - - - -	624	Sq. Mi.

	Quantity	Unit
Reservoir:		
Area at spillway stage - - - - - - - -	5,647	Acres
Storage capacity at spillway level, 1913	274,065	Ac. Ft.
Capacity per square mile of drainage area: 2/		
1913 - - - - - - - - - - - - - - - -	439.2	Ac. Ft.
1937 - - - - - - - - - - - - - - - -	428.9	Ac. Ft.
1948 - - - - - - - - - - - - - - - -	424.8	Ac. Ft.
Sedimentation:		
Total sediment:		
1913-1937 - - - - - - - - - - - - -	6,435	Ac. Ft.
1937-1948 3/ - - - - - - - - - - - -	2,555	Ac. Ft.
1913-1948 - - - - - - - - - - - - -	8,990	Ac. Ft.
Average Annual Accumulation:		
From the entire drainage area:		
1913-1937 - - - - - - - - - - - - -	269	Ac. Ft.
1937-1948 - - - - - - - - - - - - -	226	Ac. Ft.
1913-1948 - - - - - - - - - - - - -	255	Ac. Ft.
Per square mile of drainage area: 4/		
1913-1937 - - - - - - - - - - - - -	0.43	Ac. Ft.
1937-1948 - - - - - - - - - - - - -	0.36	Ac. Ft.
1913-1948 - - - - - - - - - - - - -	0.41	Ac. Ft.
Depletion of Storage:		
Loss of original capacity:		
Per year:		
1913-1937 - - - - - - - - - - - -	0.10	Percent
1937-1948 - - - - - - - - - - - -	0.08	Percent
1913-1948 - - - - - - - - - - - -	0.09	Percent
Total:		
1913-1937 - - - - - - - - - - - -	2.35	Percent
1937-1948 - - - - - - - - - - - -	0.93	Percent
1913-1948 - - - - - - - - - - - -	3.28	Percent

1/ Storage began March 1913. Average date of first survey was January, 1937. Average date of second survey was May, 1948.
2/ Including area of lake.
3/ Summary data for 1948 based on re-survey of 7 segments. These data were applied proportionately to the other segments of the lake.
4/ Excluding area of lake.

Sedimentation in Medina Irrigation System

Since Medina Lake has a very high trap efficiency, the water diverted from it through the main irrigation canal and its subsidiary ditches is reasonably free from sediment. However, some sediment is produced by erosion of the canal banks during periods of release flow. The greatest contribution of sediment to the irrigation canals is derived from sheet erosion of the upland. These sediment deposits encourage the growth of brush, weeds, moss and aquatic plants which reduce the canal capacity. A principal part of the annual maintenance charges on the system is for cleaning the canals and ditches. This cost has been estimated by irrigation district officials at more than $2,000 annually per mile of canal.

The recommended program will have a beneficial effect by reducing the sediment damage to the irrigation canals and ditches within the watershed.

Sediment damage to irrigated lands by deposits from overflow of streams is not serious since the frequency of overflow on the irrigated areas is low.

APPENDIX V

RECOMMENDED PROGRAM

The problems encountered in developing and evaluating a recommended program for runoff and waterflow retardation and soil erosion prevention for the various conditions encountered within the San Antonio River Watershed were studied through a sampling method. Small watershed areas which were typical of the various problem areas in soil conservation or of sub-problem areas within them were selected and examined in detail. The conclusions and recommendations derived from these intensive investigations in sample watersheds were then expanded to the area of which they were typical, figure 38. Sufficient examinations were made in each of the large areas to assure that the conclusions reached in the sample were valid for the whole area. Land treatment and stabilizing measures and the resulting benefits and costs for the individual sample areas were expanded to the comparable expansion area.

The expansion of flood prevention measures was carried out in the same manner. In some areas sites were not available or flood damages were too small to justify recommending floodwater retarding structures at this time. In the expansion of data consideration was given to these conditions.

Measures and practices applicable to the various problem areas in soil conservation were considered and a determination was made as to which measures were of primary importance to the objectives of runoff and waterflow retardation and soil erosion prevention. Soil Conservation Service work unit personnel, regional technicians and other agricultural workers were consulted concerning the need for, and the feasibility of, measures in determining whether they should be included in the recommended program.

In analyzing the effects and costs of measures or combinations of measures the following groupings were made: 1/

1. Those parts of the going agricultural programs in the watershed which were deemed of primary importance to the objectives of the Flood Control Act. It was assumed that the application of such measures would continue at a rate at least equal to the present rate, as shown by records of agricultural agencies for the period 1947 through 1950. Since the measures in this group are currently being installed, the portions which can be expected to be installed during the evaluation period are not included in the recommended program nor are they discussed in detail; see 2 (a) below.

1/ Pages 1 and 2 of the Secretary's Memorandum, dated September 29, 1949; Subject: "Policies and Procedures to Guide the Preparation of Flood Control Survey Reports," as amended and supplemented, January 6, 1950.

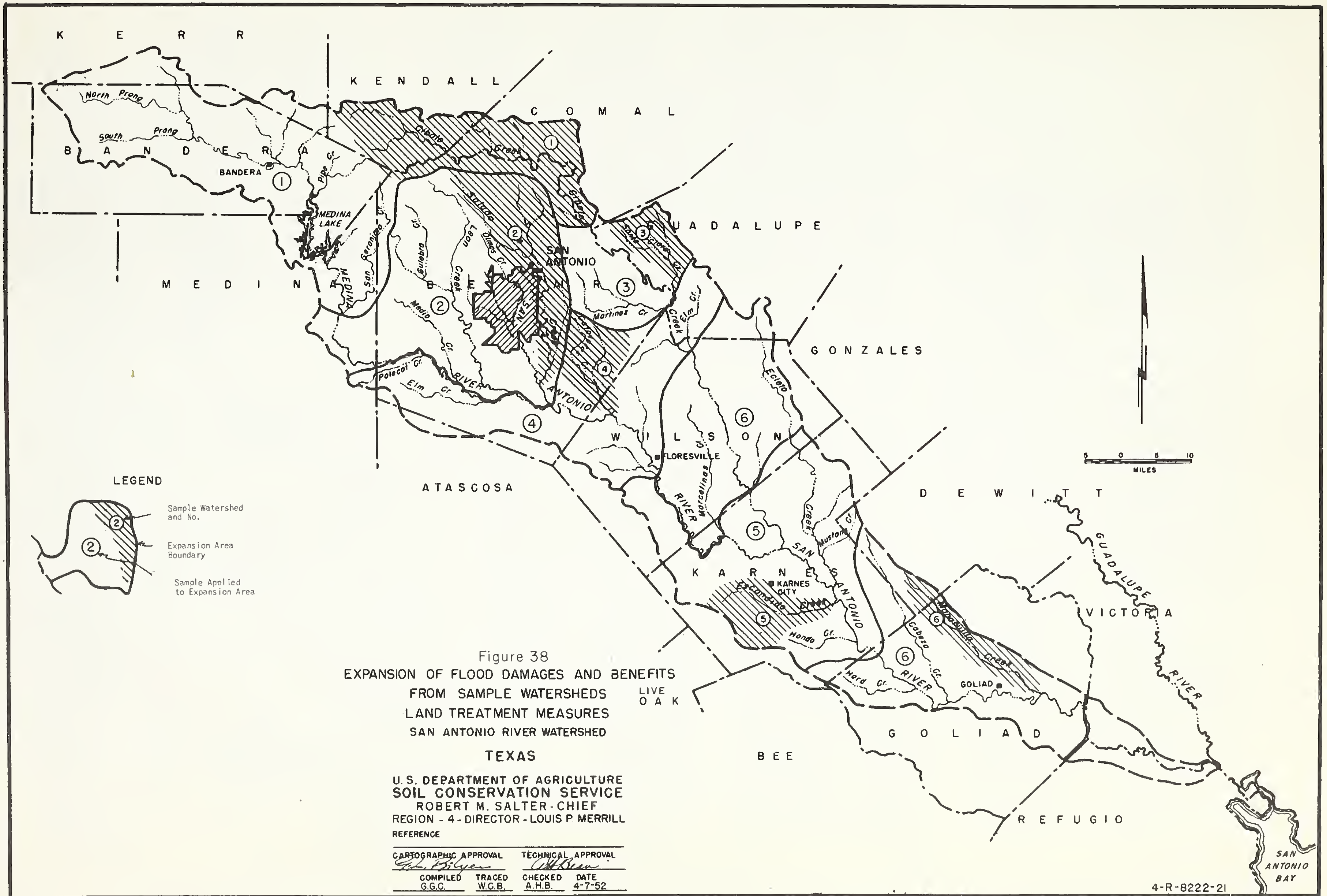


Figure 38
EXPANSION OF FLOOD DAMAGES AND BENEFITS FROM SAMPLE WATERSHEDS LAND TREATMENT MEASURES
SAN ANTONIO RIVER WATERSHED
TEXAS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
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REGION - 4 - DIRECTOR - LOUIS P. MERRILL

2. The program recommended in this report is as follows:

(a) The acceleration, intensification, or adaptation of such portions of the going programs to the extent necessary to achieve flood prevention objectives. This portion of the recommended program is called land treatment and stabilizing measures.

(b) Additional measures not now regularly installed but considered necessary to complete a balanced runoff and waterflow retardation and soil erosion prevention program for the watershed. This portion of the recommended program is called flood prevention measures.

The present speed of application of measures under the going programs and the possibilities of acceleration were considered in estimating the time which would be necessary to apply the recommended program. It was decided that an installation period of approximately 15 years would be necessary for completion of the recommended land treatment and stabilizing measures on substantially all farms and ranches in the watershed. Flood prevention measures can be applied almost immediately but should not be installed until a major portion of their drainage area has been treated to reduce soil loss and sediment output rates.

Investigation of damages and possible benefits showed that the acceleration of land treatment and stabilizing measures was justified in nearly all of the watershed and would result in substantial reductions of damages. Figure 38 shows the small flat area in Victoria and Refugio counties on which no acceleration is recommended at this time.

The following tabulation shows the present annual (going) rate of application of land treatment and stabilizing measures and also the total amount which would be established by the going program during the 15-year acceleration period:

Measures	Unit	Present Annual Rate of Application	Amount which will be established in a 15-year period by the Going Program
Terraces	Miles	273	4,095
Field Diversions	Miles	10	150
Cover Crops	Acres	11,908	178,620
Farm and Group Waterways	Miles	16	240
Establishment of New Grassland	Acres	1,171	17,565
Improvement and Management of Existing Grassland	Acres	66,633	994,495

The following sections describe the measures included in the recommended program. Installation costs include the cost of the first application or construction. Quantities of measures, costs of installation,

and the distribution of these costs are presented in table 39. The installation cost by major groupings and the number of floodwater retarding structures, for creek watersheds or sections of river watersheds are shown in table 40.

Maintenance of the land treatment stabilizing flood prevention measures on private land is considered the responsibility of local or private interests. The estimated costs are shown as non-Federal, but it is recognized that the Department of Agriculture has responsibilities to see that the maintenance is carried out to the extent that the going programs of the Department cannot meet these requirements of maintenance. The Secretary of Agriculture may request funds under appropriate authorities for carrying out maintenance of these measures and practices.

LAND TREATMENT AND STABILIZING MEASURES

The land use adjustments and to a large extent the application of land treatment and stabilizing measures will be carried out by farmers and ranchers. It is essential that measures and practices be planned not only to achieve the maximum utilization of the capacity of soil to absorb and hold water in this low rainfall area, but also to accomplish this objective without unduly disrupting the economy of the area.

All of the watershed is included within soil conservation districts, figure 7, Appendix II. The work plans and programs of these districts set up land use and treatment standards which reflect the best judgment and information available on soil and water conservation. Application of these measures has been in progress for several years and treatment has been initiated and partially completed on about 629,000 acres, or 24 percent of the area in the watershed where acceleration of treatment is recommended.

Terraces

All cultivated land subject to damaging erosion, except deep, coarse textured soils, will be terraced. Terraces reduce sheet erosion and inhibit the development of gullies by decreasing the length of slope over which runoff water travels and by collecting runoff water into protected channels. The reduced velocity of runoff reduces the amount of sediment or soil which it can carry through the terrace channels. The estimated installation cost of terraces is $140 per mile and the annual maintenance cost is estimated to be 10 percent of the installation cost. Since the entire watershed is subject to very high intensity storms no level closed-end terraces are planned.

Field Diversions

Field diversions will be constructed to intercept and route runoff to selected points in order to protect severely eroded areas, valuable cropland, or local high damage areas. In some cases field diversions

Table 39. Quantities of Measures and Distribution of Costs of the Recommended Program

San Antonio River Watershed, Texas

Measures	Unit	Quantity	Cost: Federal	Cost: Non-Federal: Public	Cost: Non-Federal: Private	Total
			(dollars)	(dollars)	(dollars)	(dollars)
Land Treatment and Stabilizing Measures						
Terraces	Mile	13,265	1,050,668	0	805,735	1,856,403
Field Diversions	Mile	332	77,124	0	36,012	113,136
Cover Crops	Acre	10,121	35,120	0	45,848	80,968
Farm and Group Waterways	Mile	574	77,949	0	52,924	130,873
Establishment of New Grassland	Acre	10,775	44,440	0	233,051	277,491
Improvement and Management of Existing Grassland	Acre	822,026	494,640	0	883,564	1,378,204
Subtotal	-	-	1,779,941	0	2,057,134	3,837,075
Technical Services	Acre	826,313	1,652,626	0	0	1,652,626
Educational Assistance	-	-	120,138	120,138	0	240,276
Administration of Direct Aids	-	-	143,995	0	0	143,995
Facilitating Measuring Devices	-	-	21,540	0	0	21,540
Subtotal	-	-	1,938,299	120,138	-	2,058,437
Flood Prevention Measures						
Floodwater Retarding Structures	No.	85	5,576,774	828,737	0	6,405,511
TOTAL	-	-	9,295,014	948,875	2,057,134	12,301,023

Table 40. Installation Costs by Creek Watersheds or Sections of River Watersheds and the Number of Floodwater Retarding Structures

San Antonio River Watershed, Texas

Creek Watershed or Section of River Watershed	Recommended Land Treatment and Stabilizing Measures	Technical Education & Administration	Flood Prevention Measures	Floodwater Retarding Structures
	(dollars)	(dollars)	(dollars)	(number)
Upper San Antonio	987,688	532,791	2,185,041	25
Lower San Antonio	753,899	407,903	1,404,377	13
Upper Medina	173,698	217,934	0	0
Lower Medina	594,376	332,783	467,495	7
Upper Cibolo	97,779	100,180	0	0
Lower Cibolo	898,728	311,486	1,347,582	31
Ecleto	330,907	133,820	1,001,016	9
Total	3,837,075	2,036,897	6,405,511	85

will be used as the top terrace in a terrace system. Cost per mile is estimated to be $341 and annual maintenance is estimated to be 3 percent of the installation cost.

Farm and Group Waterways

Natural and constructed waterways, including terrace outlets, will be stabilized by use of vegetation and structures to reduce sediment yields and land destruction resulting from the concentration of runoff. These channels will be shaped where necessary and a vegetative cover established by seeding or sodding of adapted grasses, fertilization and management, to offer maximum protection to the waterway. These waterways will safely carry the discharge from terraces, diversion terraces, or other structures, and will supplement the natural surface collection and drainage system of the area.

The estimated installation cost is $228 per mile and annual maintenance is estimated to be 5 percent of the installation cost.

Terraces, diversions, and waterways comprise the runoff water disposal system of the farm area. Other measures which retard runoff and soil losses fit within this framework and will hold as much as possible of the usable water on the fields. The disposal systems will carry the excess in a safe and orderly manner to the natural stream courses.

Cover Crops

The use of annual or perennial legumes or closely seeded crops to protect cropland areas during seasons when the soil surface would be bare of vegetation decreases runoff and soil loss by increasing the rate of water penetration into the soil and slowing the rate of runoff overland. The cost of initial installation of this practice is estimated to be $8 per acre, which includes seed, fertilizer, and planting costs. The cost of recurrent planting of cover crops is included in the increased cost of operating a more profitable system of farming, Appendix VI.

Other Cropland Conservation Measures

Additional farm practices are necessary on cultivated areas to retard runoff and protect the soil from erosion. All crops will be planted and cultivated on the contour to reduce the concentration of runoff, except where erosion is negligible and drainage is the major problem. Crop residue management and conservation crop rotations will be practiced on nearly all cultivated land to improve the physical condition of the soil, which will promote infiltration of rainfall into the soil. Improvement of the physical condition, gain in soil fertility, and enhancement of water-holding capacity resulting from these management practices also will reduce runoff and soil loss through an increased vegetative cover and more efficient utilization of available rainfall. A large percentage of these practices will be applied through the going programs and their use is becoming widespread. As these measures are rapidly becoming

a part of the farming system without noticeable increases in farm operating costs, installation costs were not considered.

Establishment of New Grassland

Approximately 22,119 acres of land which is now cultivated or lying idle should be converted to pasture or range land. The capability of this land is such that it cannot be continuously and profitable cultivated, but it can be developed into good or excellent cover with a reasonable expenditure. Fertilizing and seeding are the major items of expense and will vary from $25 to $29 per acre. The management costs of this new pasture will be the same as any other pasture and the reduction in flood and sediment damages due to the soil cover improvement will reach far beyond the areas actually improved. These and other land use changes are shown in table 41.

Improvement and Management of Existing Grassland

A large group of measures is included under this heading. Measures such as proper stocking, salting and establishing a water supply for livestock use are beneficial to grassland but since they are management practices which should be followed universally no costs are considered. The improvement of the cover on existing grassland will reduce flood and sediment damages materially. The estimated costs for fertilizing and seeding vary from $8 to $12 an acre in a large part of the area. The estimated cost of clearing of scattered trees on a small portion varies from $5 to $15 per acre. Somewhat over 12,000 acres of the grassland are wooded and this cover is very effective in reducing surface runoff. In the case of wooded thin or rocky soils, if cleared it is doubtful that a grass cover could be established which would be as effective in reducing runoff as the present woods cover. Clearing, therefore, is recommended only on areas of wooded deep soils.

Technical Services

Technical services will be made available to owners, operators and administrators of farm and ranch lands to assist in planning and applying the necessary land use adjustments and for planning and applying the land treatment practices and measures, including integration with other measures included in the recommended program. The cost of furnishing these services is a Federal cost and is approximately $2 per acre on the areas in which acceleration is recommended. The total cost for the 15-year period is estimated to be $1,652,626.

The estimated installation costs of flood prevention measures include engineering and design costs of structures.

Educational Assistance

Land owners and operators will be furnished educational assistance. They will be supplied information as to the manner in which services and assistance are made available through the various governmental agencies

Table 41. Present and Future Land Use by Problem Areas in Soil Conservation

San Antonio River Watershed, Texas

	Edwards Plateau	Rio Grande Plain	Blackland Prairie	Forested Coastal Plain	Coast Prairie	Total
	(acres)	(acres)	(acres)	(acres)	(acres)	(acres)
Non-Farmland	11,231	80,304	891	1,464	226	94,116
Farmland	740,754	1,683,277	63,838	79,171	17,884	2,584,924
Total	751,985	1,763,581	64,729	80,635	18,110	2,679,040
Present Condition						
Cropland	44,548	549,993	46,106	14,845	6,248	661,740
Grassland	681,815	1,122,777	16,032	18,010	10,175	1,848,809
Woodland Pasture	13,469	0	1,567	45,853	1,428	62,317
Miscellaneous	922	10,507	133	463	33	12,058
Total	740,754	1,683,277	63,838	79,171	17,884	2,584,924
Future Condition						
Cropland	41,565	534,144	43,338	14,330	6,244	639,621
Grassland	698,267	1,138,626	20,367	64,378	11,607	1,933,245
Miscellaneous	922	10,507	133	463	33	12,058
Total	740,754	1,683,277	63,838	79,171	17,884	2,584,924

and how they, by their own efforts, can contribute most economically to the success of the program. Intensified educational efforts will be directed to familiarizing farmers with the recommended practices and measures, how to install and apply measures not requiring technical assistance. The cost of providing educational assistance on a creek watershed basis was estimated by the Agricultural Extension Service.

The cost of educational assistance per acre to be treated by the accelerated program and per square mile of watershed is approximately as follows:

Per Acre	Per Square Mile
$0.29	$57.40

Administration of Direct Aids

The recommended program includes the payment of direct aids to individual farmers and ranchers by the Federal Government to defray portions of the cost of certain measures. The Federal contribution is based upon the present rates of payment per unit of measure applied. Payments on the measures to be applied as a part of the recommended program during the 15-year period of installation would not duplicate payments made under the going program. The cost of administering these direct aids is 8.0 percent of the payments and will approximate $143,995.

FACILITATING MEASURES

Hydrologic Studies to Facilitate Program Installation

It is recommended that measuring devices be installed on selected segments of creek watersheds to obtain information on rainfall and runoff from streams to facilitate installation of the recommended program. The measurements will include:

(a) Measurement of precipitation and determination of rainfall-runoff relationship.

(b) Determination of flood hydrographs on small and moderate-sized drainage areas to assist in design of remedial measures and flood routing.

It is recommended that 6 lake-level gages, 3 streamflow gages and 30 precipitation gates be located in Calaveras and Escondido Creeks to accomplish this.

Cost of the installation and operation and maintenance of the gages and analysis of data are as follows:

Cost of installing 9 water stage recorders	$18,000
Cost of installing 30 rain gages	3,540
Total	$21,540

Annual operation, maintenance and analysis of records, water-stage recorders	$7,200
Annual operation, maintenance and analysis of records, rain gages	4,600
Total	$11,800
Cost of operation, maintenance and analysis of records for 15-year period	$177,000

FLOOD PREVENTION MEASURES

Floodwater Retarding Structures

Surveys of possible sites for floodwater retarding structures were made in 6 sample watersheds within the San Antonio River Watershed. Investigations were made, in areas to which data from the sample watersheds were expanded, to insure proper application of the data. The physical and economic effects of systems of floodwater retarding structures were evaluated by flood routing methods described in Appendices III and IV. It was determined that systems of structures, located on certain creeks and their branches, are feasible and are needed to reduce the frequency and severity of flooding on the flood plains below. The total cost of installation is estimated to be $6,405,511. The areas in which such structures are needed and feasible under present condtions are delineated in figure 39. Approximately 85 floodwater retarding structures are recommended in the watershed at this time. The approximate number of these structures are shown by creek watersheds or sections of river watersheds in table 42, and pertinent information by sample watersheds is shown in table 43.

The typical structure was so located as to protect the maximum area of cultivated, or formerly cultivated, alluvial lands which are frequently overflowed. The structures were located and designed to reduce the peak flows from most of the flood-producing storms to less than channel capacity. This will achieve substantial reduction in flood damage and make it possible to use flood plain lands more intensively.

The volume of retarding storage in each structure will be sufficient to detain the runoff expected from a storm of at least a 25-year frequency in addition to the amount discharged by the draw-down tube during the period of watershed runoff.

The areas in which floodwater retarding structures are recommended, figure 39, are characterized by small farms. It is anticipated that the structure sites will be provided by local interests. When conditions are such that structure sites cannot be obtained by local interests, the sites will be provided at Federal expense. Whenever possible, title to these sites should rest with the non-Federal interests responsible for the operation and maintenance of the structures. The annual maintenance cost is estimated to be an average of $200 per structure.

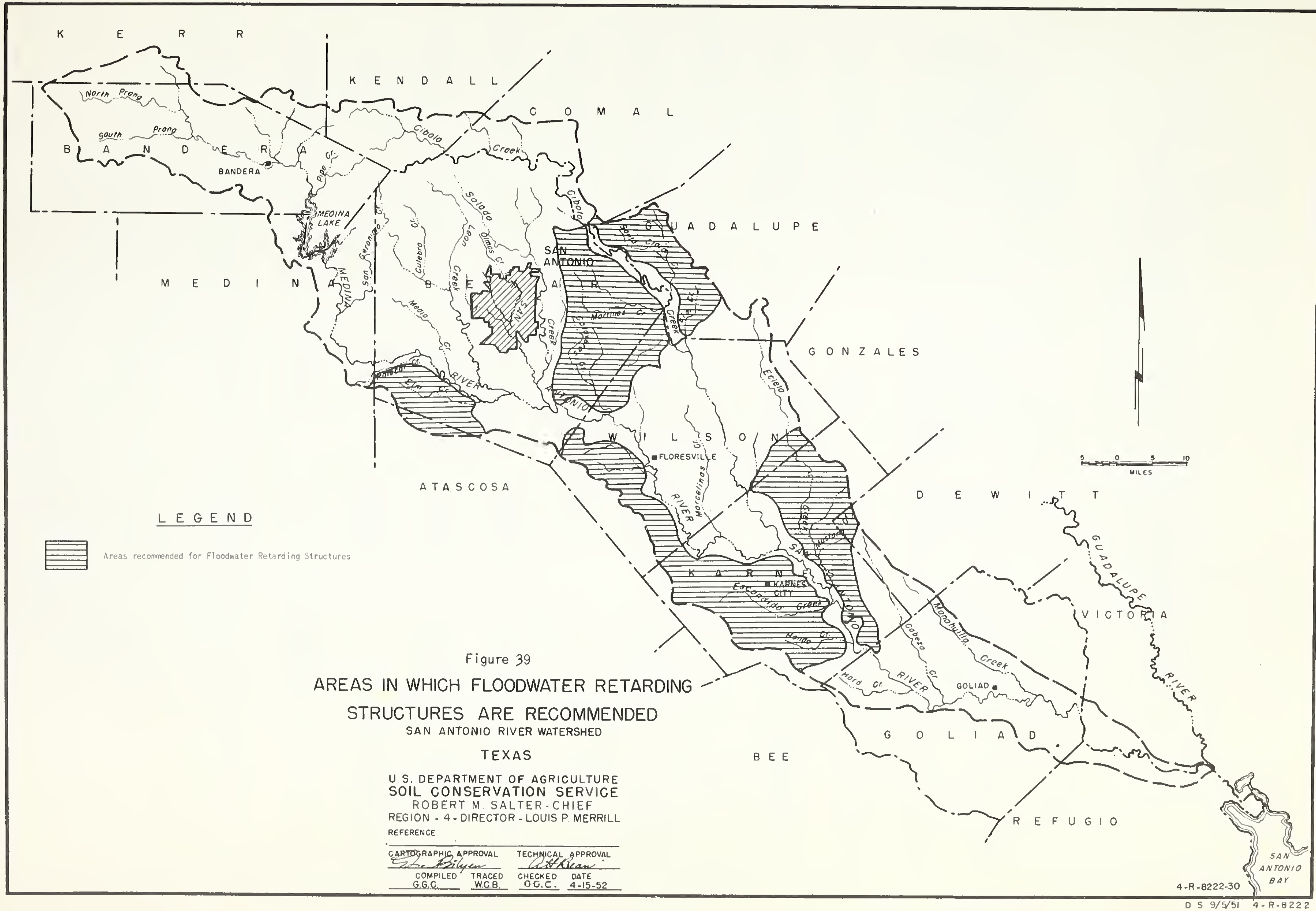


Figure 39

AREAS IN WHICH FLOODWATER RETARDING STRUCTURES ARE RECOMMENDED

SAN ANTONIO RIVER WATERSHED

TEXAS

Table 42. Number and Size of Floodwater Retarding Structures by Creek Watersheds or Sections of River Watersheds.

San Antonio River Watershed, Texas

Creek Watershed or Section of River Watershed	Number of Structure	Ac. Ft. Detention Storage per Structure	Total Acre Feet Flood Storage	Cubic Yard Fill per Structure	Total Cubic Yards of Fill
Upper San Antonio	25	2,829	70,724	141,783	3,544,563
Lower San Antonio	13	3,376	43,893	182,624	2,374,111
Upper Medina	0	0	0	0	0
Lower Medina	7	2,259	15,815	102,352	716,461
Upper Cibolo	0	0	0	0	0
Lower Cibolo	31	1,098	34,035	59,917	1,857,414
Ecleto	9	3,476	31,286	188,025	1,692,227
Total	85		195,753		10,184,776
Average		2,303		119,821	

Table 43. Pertinent Data on Floodwater Retarding Structures Recommended for Construction by Sample Watersheds

San Antonio River Watershed, Texas

Site Number	Drainage Area		Storage Volume				Surface Area		Flood Plain Inundated		Maximum Height of Fill	Volume of Fill	Draw Down Rate
		Detention Pool		Permanent Pool	Reserve	Total	Top of Permanent Pool	Top of Detention Pool	Permanent Pool	Spillway Crest			
	(sq. mi.)	(inches)	(ac. ft.)	(ac. feet)	(ac. ft.)	(ac. ft.)	(acres)	(acres)	(acres)	(acres)	(feet)	(cu.yds.)	(c.s.m.)
							Calaveras Creek 1/						
2	5.83	4.6	1,430	187	0	1,617	44	177	0	105	26.0	66,817	4.0
3	1.62	4.6	398	69	0	467	27	63	0	0	15.5	43,416	4.0
4	2.21	4.6	542	82	0	624	19	75	0	0	19.6	62,469	4.0
8	5.58	4.6	1,369	179	0	1,548	53	160	0	105	20.0	127,510	4.0
9	4.77	4.6	1,170	165	0	1,335	47	155	0	86	24.7	76,199	4.0
16	20.84	8.8	9.781	356	146	10,283	75	820	44	278	36.7	299,584	4.0
18	6.66	4.6	1,634	114	99	1,847	25	182	5	16	29.8	63,539	4.0
Total			16,324	1,152	245	17,721	280	1,632	49	590		739,534	
							Escondido Creek 2/						
3	8.6	7.2	3,302	413	0	3,715	67	219	6	20	33.3	156,380	4.0
3A	5.7	5.0	1,520	274	0	1,794	44	145	4	13	33.3	103,880	4.0
4	12.2	9.2	5,986	521	0	6,507	86	450	18	93	32.8	223,720	4.0
5	10.3	7.9	4,340	439	0	4,779	81	418	18	93	28.6	214,240	4.0
6	5.1	5.0	1,360	272	0	1,632	38	189	3	13	25.2	157,100	4.0
8	9.0	7.7	3,696	312	120	4,128	61	375	8	42	32.2	246,920	4.0
10	2.2	5.0	587	129	0	716	31	100	4	13	16.5	93,200	4.0
11	13.3	9.2	6,526	518	49	7,093	23	135	16	93	36.0	282,100	4.0
Total			27,317	2,878	169	20,364	431	2,031	77	380		1,477,540	
							Santa Clara Creek 3/						
2	3.2	4.7	802	205	0	1,007	43	160	7	32	19.1	53,880	4.0
4	1.5	4.7	376	112	0	488	32	74	3	12	12.3	58,800	4.0
2A	2.5	4.7	627	160	0	787	33	126	5	26	19.1	42,100	4.0
2B	1.8	4.7	451	115	0	566	24	90	3	18	19.1	30,300	4.0
3A	1.8	4.7	451	115	0	566	24	90	3	18	10.8	30,300	4.0
3B	3.1	4.7	777	198	0	975	42	156	6	31	10.8	52,200	4.0
3C	3.3	4.7	827	211	0	1,038	44	166	6	33	10.8	55,560	4.0
5	2.0	4.7	501	128	0	629	30	82	3	17	15.2	29,100	4.0
Total			4,812	1,244	0	6,056	272	944	36	187		332,240	

1/ Thirteen additional sites investigated but not recommended at this time.
2/ Four additional sites investigated but not recommended at this time.
3/ Three additional sites investigated but not recommended at this time.

Maintenance during the period of installation, before the structure is turned over to the maintaining agency, is considered a Federal cost and is included as part of the installation cost. It is estimated at $1,000 per structure based on a 5-year period.

It is possible at some sites to provide additional storage for irrigation use. If such provision is made, all additional costs will be paid by the interested parties or organization.

Figures 40, 41 and 42 show the location of recommended floodwater retarding structure sites in the sample watersheds. Table 44 shows the costs of floodwater retarding structures in the sample watersheds computed on the following basis:

1. Earth fill at $0.40 per cubic yard. This includes stripping, core excavation, fencing, release tube, sod spillway and related costs.

2. Concrete spillways where applicable.

3. Technical services at 15 percent of items 1 and 2.

4. Contingencies at 10 percent of items 1 and 2.

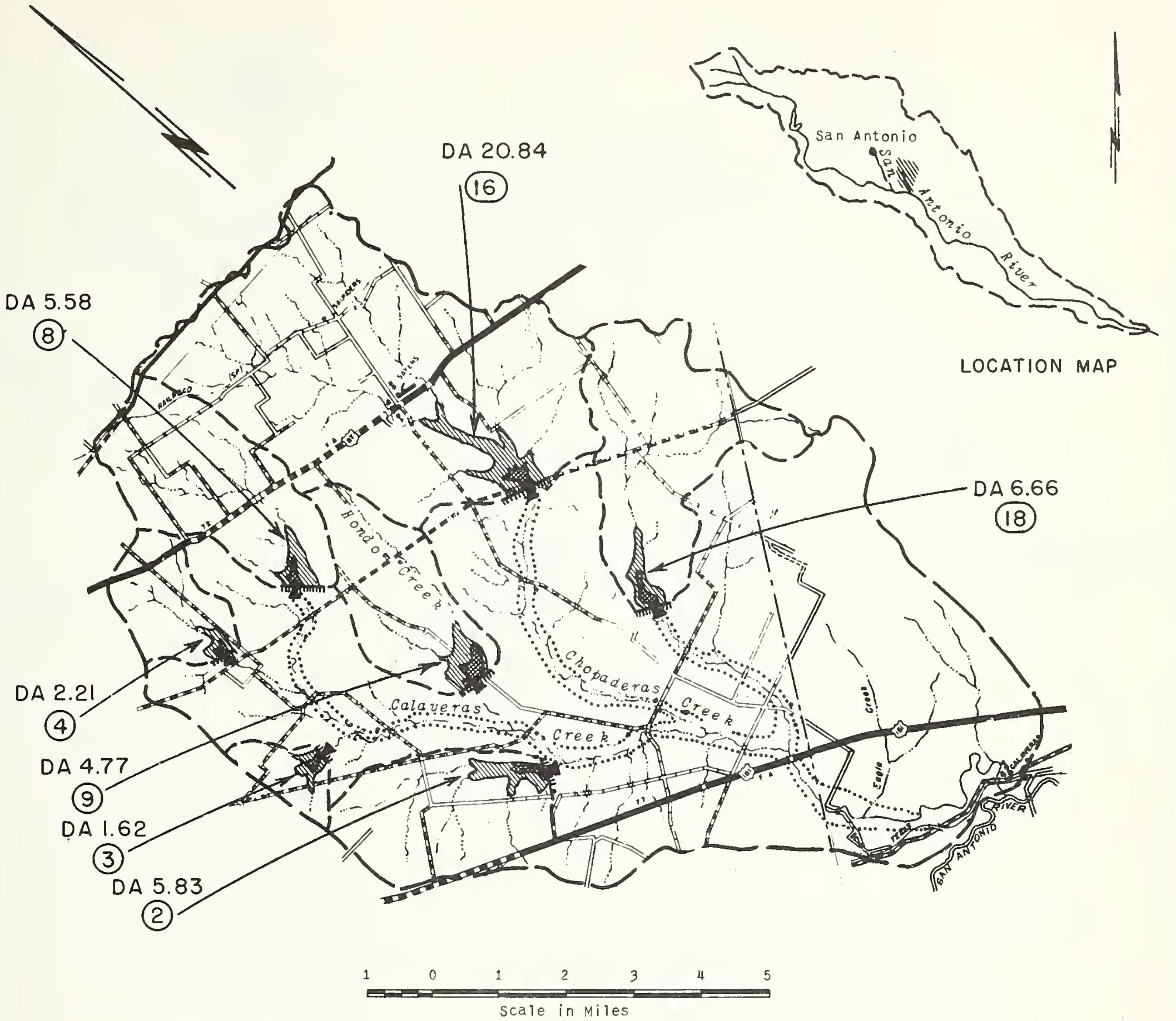
5. Replacement cost at 5 percent of items 1, 2, 3 and 4 combined.

6. Maintenance at $200 per year per site for a 5-year period during installation.

7. Land acquisition costs by individual site appraisal.

8. Farmstead and road relocation costs according to individual site estimates.

Prior to construction of floodwater retarding structures when construction of reservoirs is anticipated, detailed site investigations will be made and plans prepared as shown on pages 145, 146, 147 and 148.



LEGEND

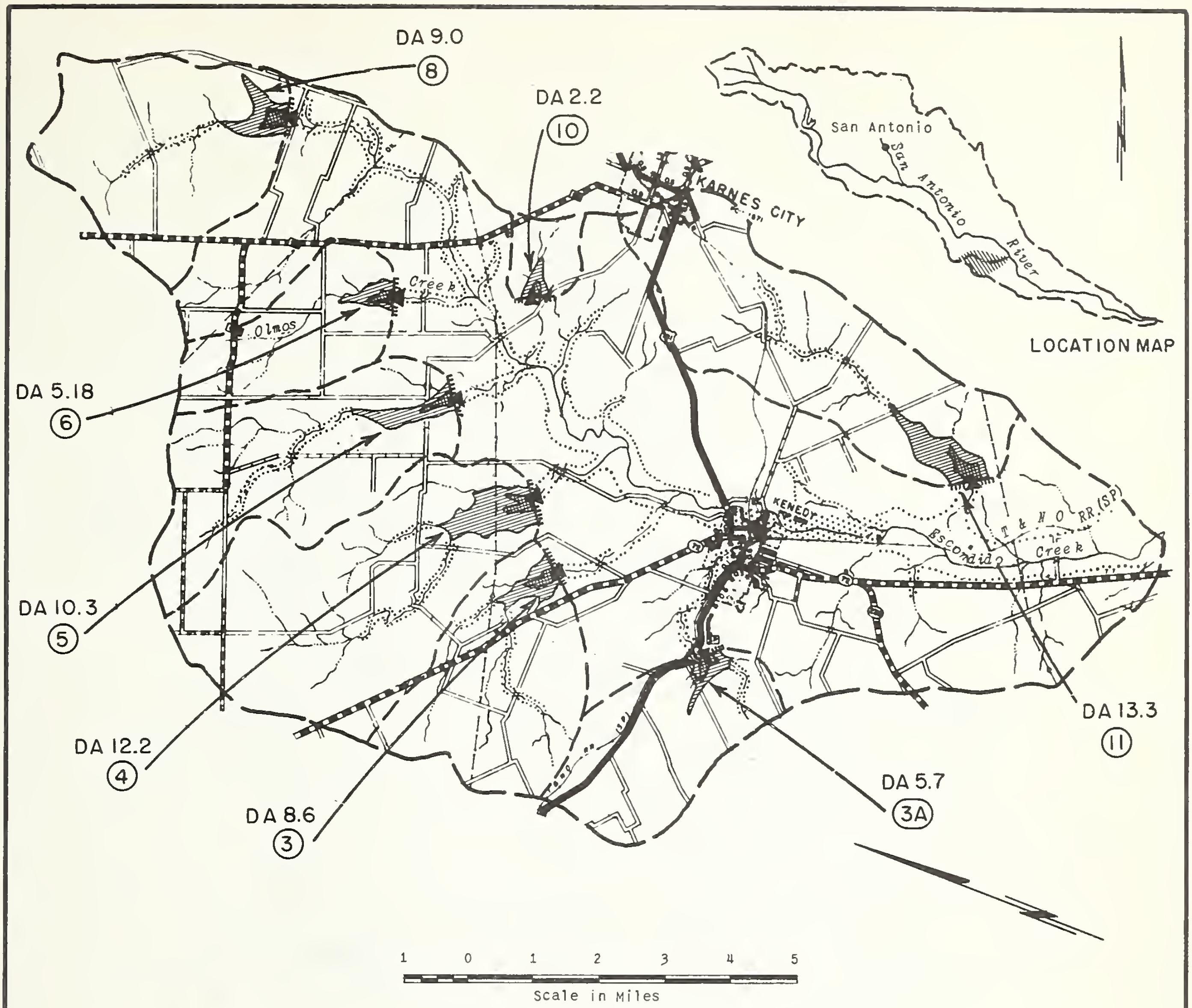
	Floodwater Retarding Structure		Watershed Boundary
9	Site No.		Drainage Area Boundary – Special Structure
DA	Square Mile Drainage Area		Drainage
	Dirt Road		Outline Flood and Sediment Damage Area
	Paved Road		Railroad
	County Line		Transmission Line

Figure 40
SAN ANTONIO RIVER WATERSHED
PLAN FOR RUNOFF AND WATERFLOW
RETARDATION AND SOIL EROSION PREVENTION
CALAVERAS CREEK SAMPLE WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL
REFERENCE

CARTOGRAPHIC APPROVAL G. L. Bilyeu TECHNICAL APPROVAL Edmond H. Hejl
COMPILED G.D TRACED R.D.B. CHECKED G.G.C. DATE 5-2-52

4-N-8222-49



LEGEND

Floodwater Retarding Structure	Drainage Area Boundary - Special Structure
(8) Site No.	Outline Flood and Sediment Damage Area
DA Sq. Mi. Drainage Area	Pipe Line
Dirt Road	Drainage
Paved Road	Railroad
County Line	Recommended Project - U. S. Corps of Engineers
Watershed Boundary	

Figure 41

SAN ANTONIO RIVER WATERSHED

PLAN FOR RUNOFF AND WATERFLOW RETARDATION AND SOIL EROSION PREVENTION

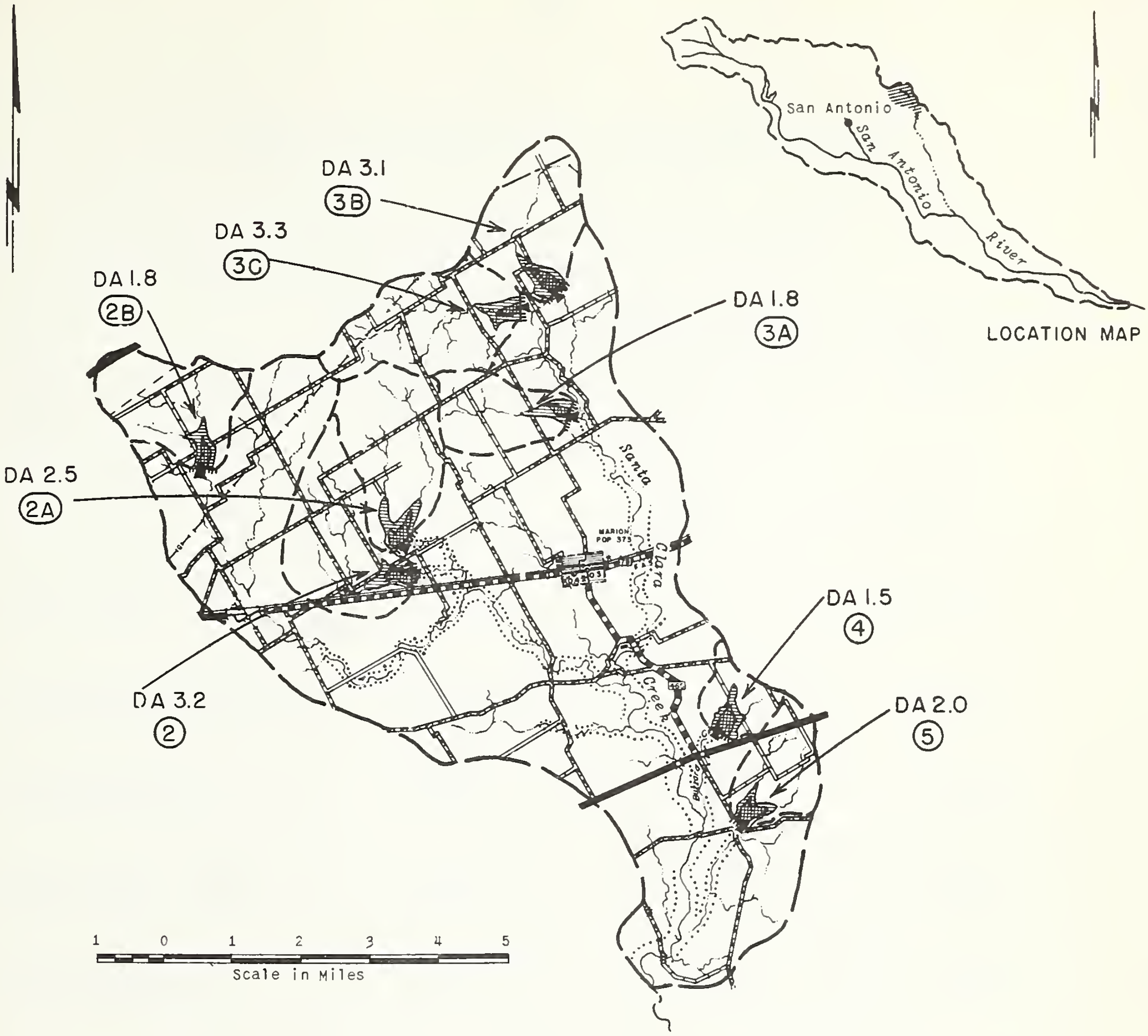
ESCONDIDO CREEK SAMPLE WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL
REFERENCE

CARTOGRAPHIC APPROVAL G. L. Blyens TECHNICAL APPROVAL Edward H. Heil

COMPILED	TRACED	CHECKED	DATE
G.D.	R.D.B	G.G.C.	5-2-52

4-N-8222-47



Floodwater Retarding Structure

⑤ Site No.

DA Sq. Mi. Drainage Area

Dirt Road

Paved Road

County Line

Watershed Boundary

Drainage

Drainage Area Boundary - Special Structure

Outline of Flood and Sediment Damage Area

Transmission Line

Figure 42

SAN ANTONIO RIVER WATERSHED

PLAN FOR RUNOFF AND WATERFLOW RETARDATION AND SOIL EROSION PREVENTION

SANTA CLARA CREEK SAMPLE WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL
REFERENCE

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
G. L. Myers		Edmund H. Heil	
COMPILED	TRACED	CHECKED	DATE
G.D.	R.D.B.	G.G.C.	5-2-52

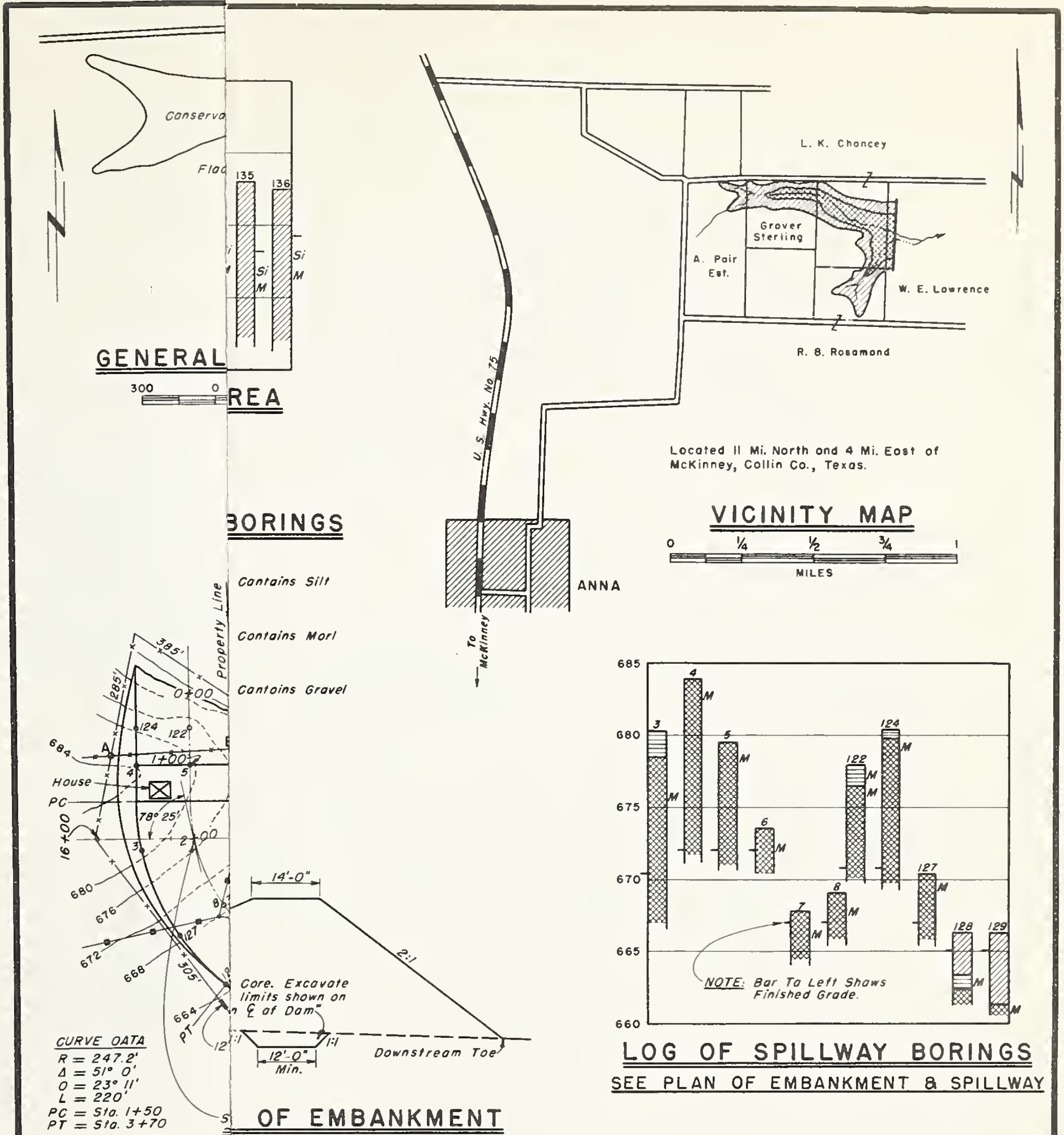
4-N-8222-48

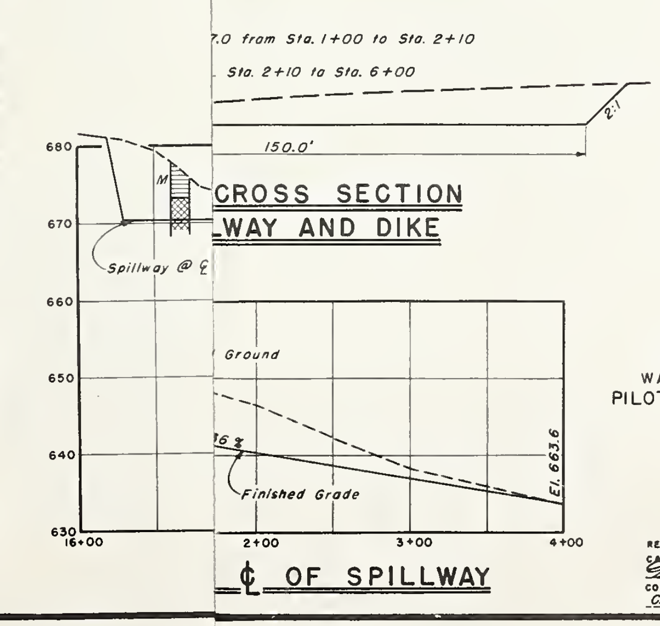
Table 44. Estimated Cost of Recommended Floodwater Retarding Structures in Sample Watersheds

San Antonio River Watershed, Texas

Item	Sample Watershed		
	Calaveras Creek	Escondido Creek	Santa Clara Creek
Number of sites	7	8	8
	(dollars)	(dollars)	(dollars)
Earth Fill	295,815	591,016	140,896
Technical Services	44,372	88,652	21,135
Contingencies	29,582	59,102	14,089
Replacement	18,488	36,939	8,807
Maintenance 1/	7,000	8,000	8,000
Site Acquisition	77,794	69,062	50,461
Farmstead Relocation	4,000	13,500	15,500
Road Relocation	5,500	7,750	7,000
TOTAL COST	482,551	874,021	265,888

1/ Cost during installation before release to the maintaining agency.





Elev.	Surface Acres	Storage * Ac. Ft.	Storage * Inches
658	14.6	113.69	1.40
660	19.5	149.09	1.82
664	27.0	242.09	3.02
668	37.3	370.69	4.52
672	48.0	541.29	6.66
676	62.5	762.29	9.37

Top of Dam (Efective) Elev. 677.0
Spillway Crest Elev. 672.0
Outlet Structure Elev. 658.0
Drainage Area 976 Ac.
*Includes Volume of Barrow

GENERAL PLAN AND PROFILES
WATERFLOW RETARDING STRUCTURE SITE NO. 7
PILOT AND SISTER GROVE CREEKS WATERSHED
OF THE
TRINITY RIVER WATERSHED
TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER-CHIEF
REGION 4 DIRECTOR-LOUIS P. MERRILL

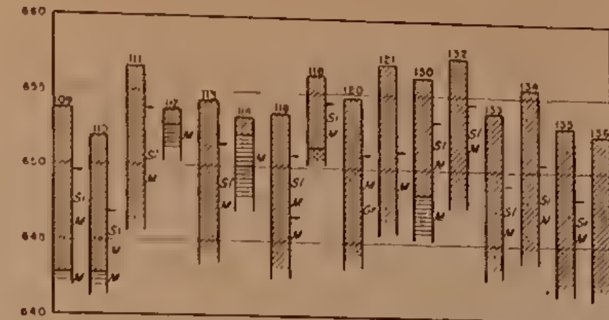
REFERENCE
CARTOGRAPHIC APPROVAL
TECHNICAL APPROVAL

COMPILED	TRACED	CHECKED	DATE
C.E.C.	J.W.M.	C.E.C.	3-12-52

4-R-8345-1

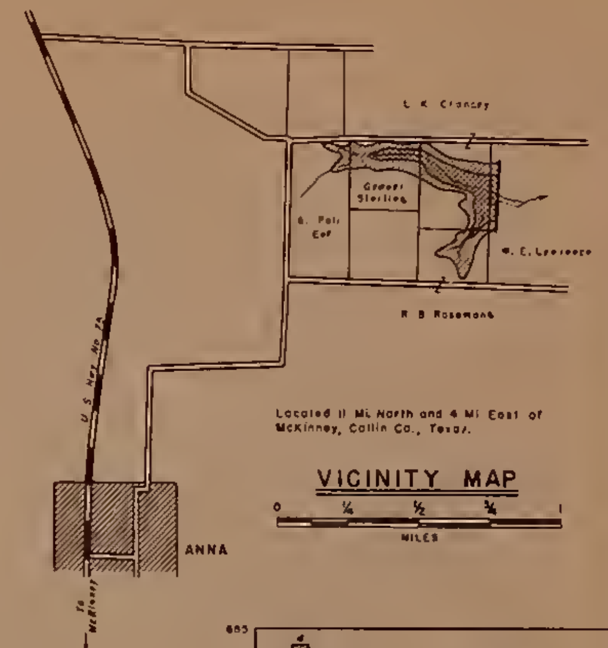
AGR-SCS-FT. WORTH, TEX.

GENERAL PLAN OF RESERVOIR



LOG OF BORINGS OF BORROW AREA

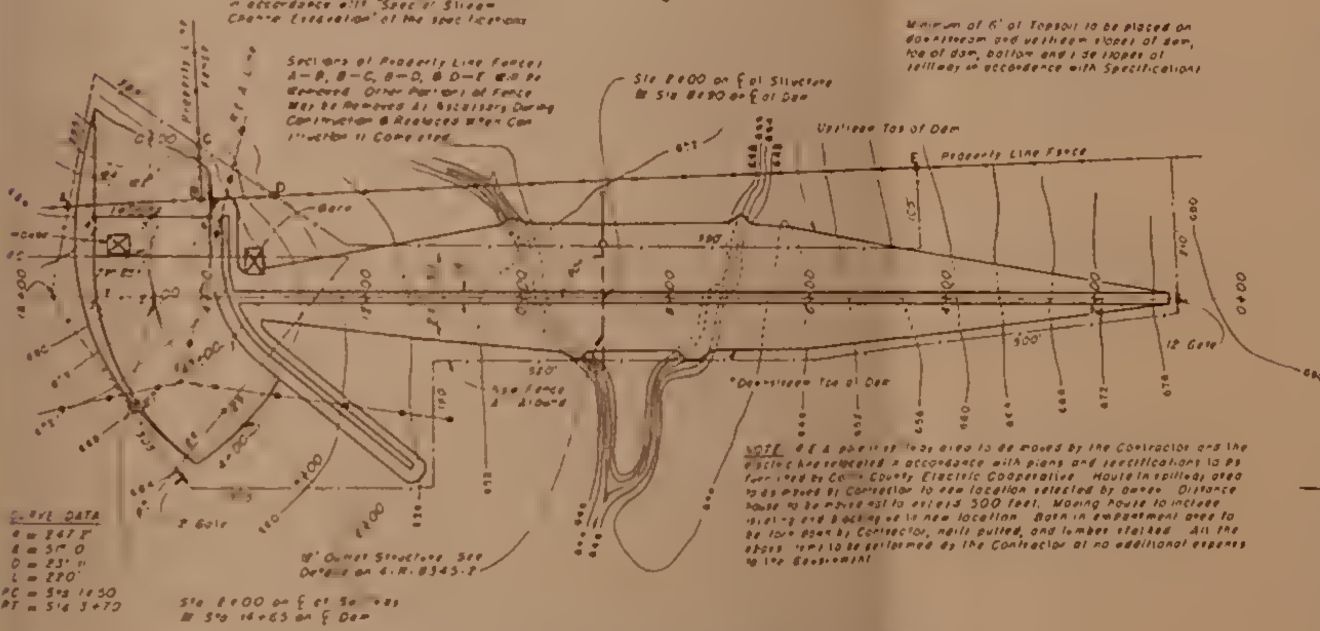
SEE GENERAL PLAN OF RESERVOIR



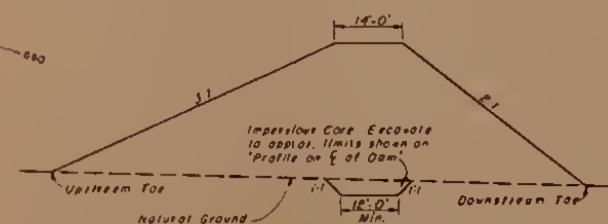
VICINITY MAP

LEGEND OF BORINGS

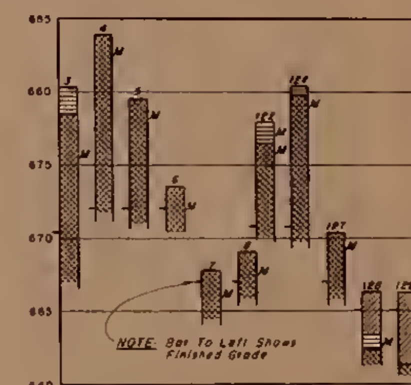
- Clay — Si Contains Silt
- Shale — M Contains Marl
- Stone — Gr Contains Gravel



PLAN OF EMBANKMENT AND SPILLWAY

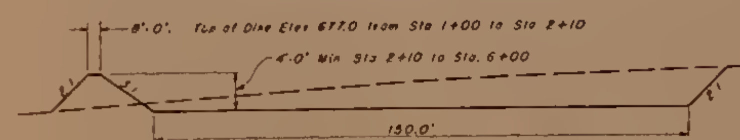


TYPICAL SECTION OF EMBANKMENT



LOG OF SPILLWAY BORINGS

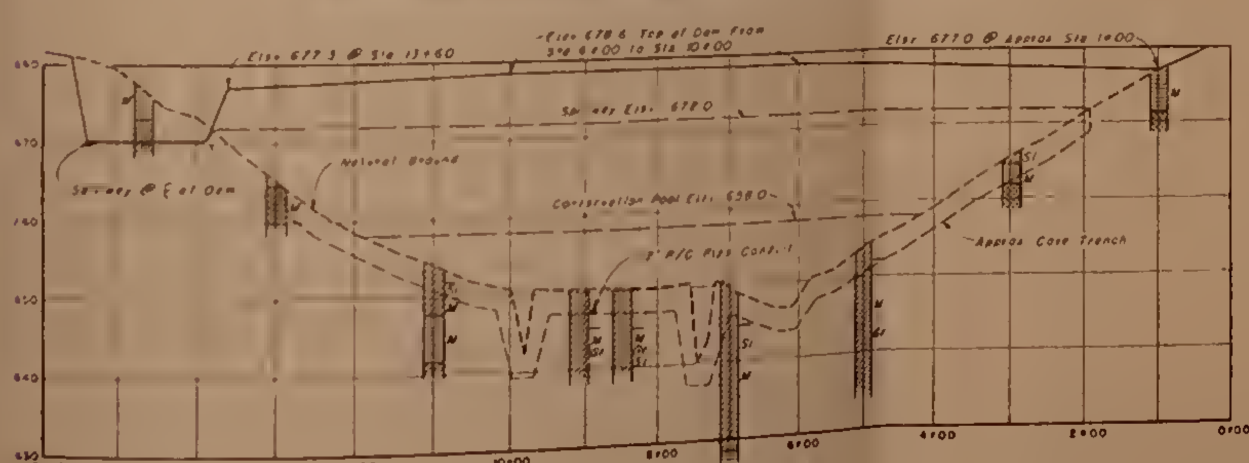
SEE PLAN OF EMBANKMENT & SPILLWAY



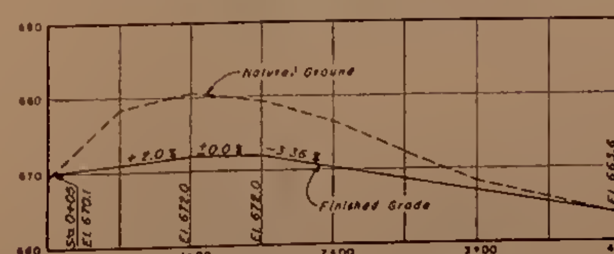
TYPICAL CROSS SECTION OF SPILLWAY AND DIKE

Elev.	Surface Acres	Storage *	
		Ac Ft	Inches
658	14.6	113.69	1.40
660	19.5	149.09	1.82
664	27.0	242.09	3.02
668	37.3	370.69	4.52
672	48.0	541.29	6.66
676	62.5	762.29	9.37
Top of Dam (Effective) Elev. 677.0			
Spillway Crest Elev. 672.0			
Outlet Structure Elev. 658.0			
Drainage Area 976 Ac.			

*Includes Volume of Borrow



PROFILE ON ℄ OF DAM



PROFILE ON ℄ OF SPILLWAY

GENERAL PLAN AND PROFILES
WATERFLOW RETARDING STRUCTURE SITE NO. 7
PILOT AND SISTER GROVE CREEKS WATERSHED
OF THE
TRINITY RIVER WATERSHED
TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL

COMPILED G.E.C. TRACED J.W.M. CHECKED G.E.C. DATE 3-12-52

4-R-8345-1

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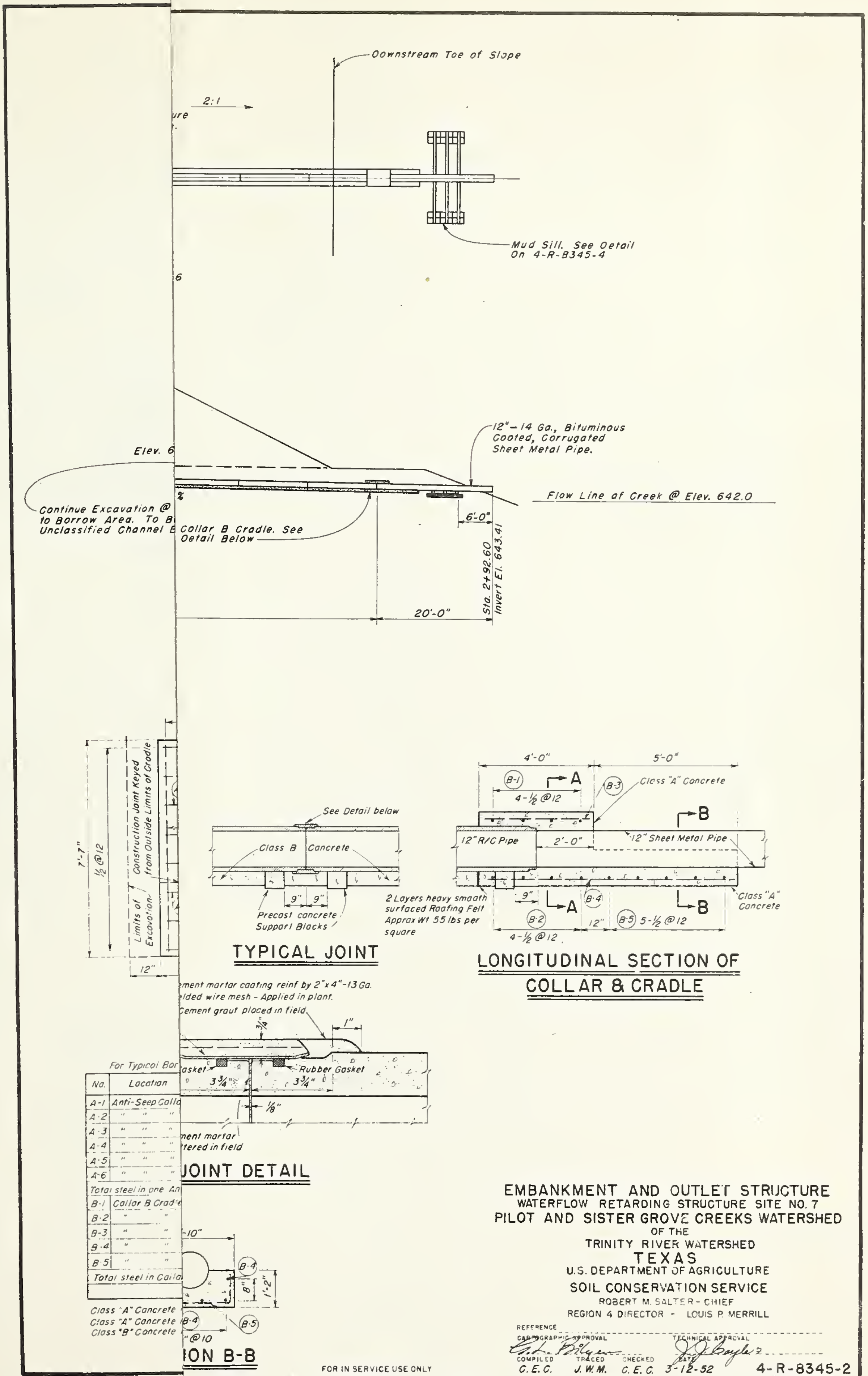
AGR-SCS-FT WORTH, TEX.



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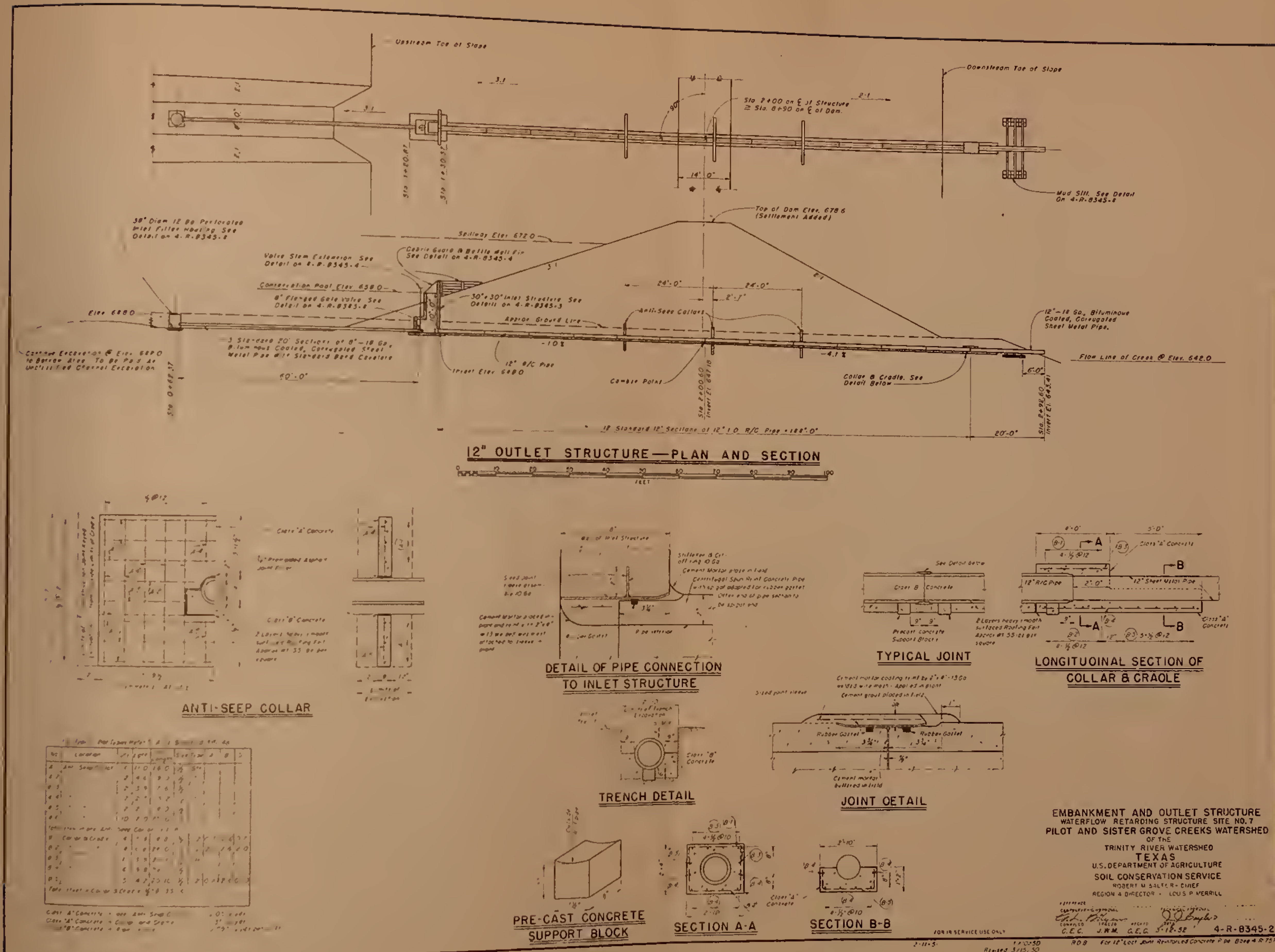

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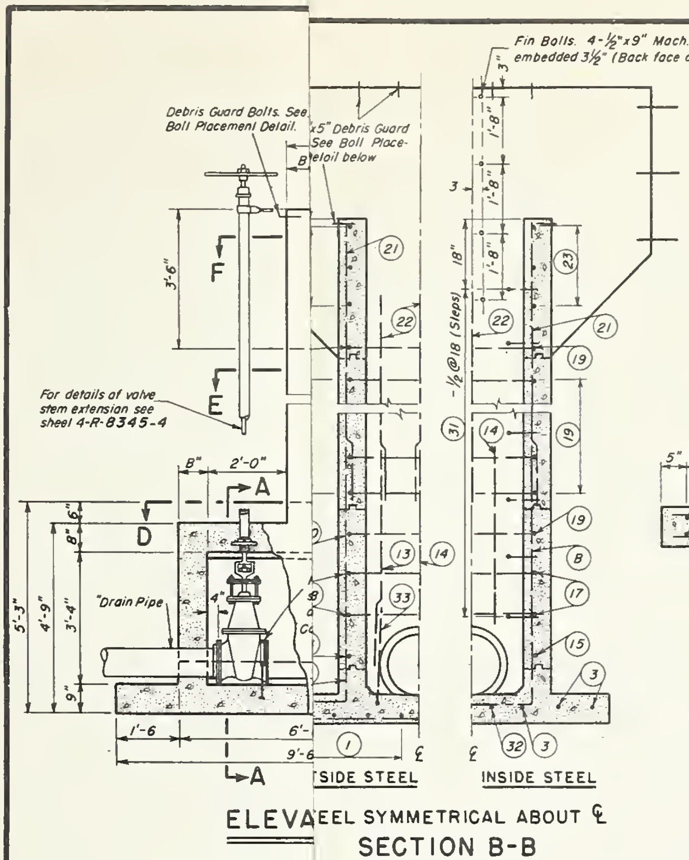
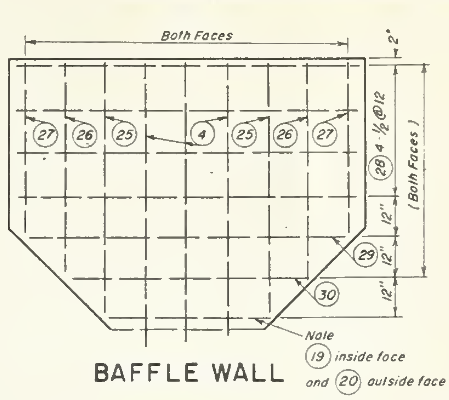
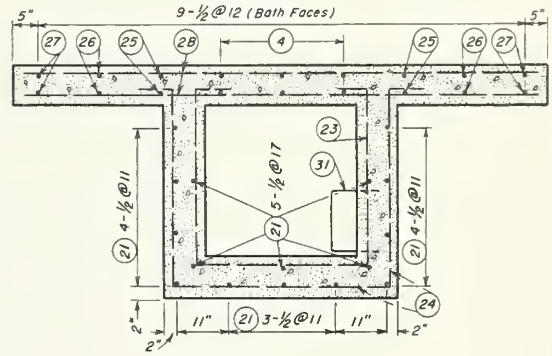


ELEVA[TION]

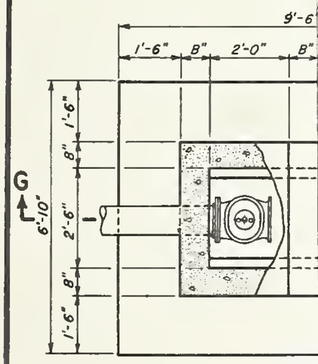
SECTION B-B



BAFFLE WALL



SECTION F-F



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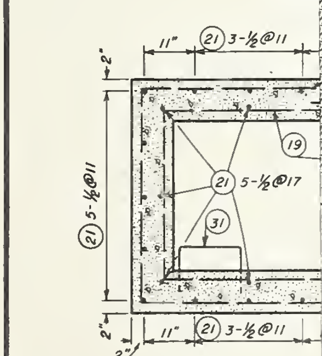

SECTION E-[E]

BAR SCHEDULE

All Dimensions are out to out   For Typical Bar Types refer to ACI Standard 315-48

Size	Length	Total Length	Type	A	B	C	O	E	F	G	H	J	K	R	O
½	10-2	81-4	1	0-6	9-2					0-6		0-4			
½	7-6	75-0	1	0-6	6-6					0-6		0-4			
½	9-2	55-0	Str.												
½	6-6	65-0	Str.												
½	5-6	33-0	2	1-6	4-0										
½	10-2	30-6	2	3-8	2-10					3-8					
½	7-10	47-0	2	1-6	6-4										
½	15-6	46-6	2	6-4	2-10					6-4					
½	8-3	33-0	8	2-11	2-8					2-8					
½	8-3	33-0	8	3-3	2-8					2-4					
½	4-8	14-0	2	0-7	3-6					0-7					
½	4-0	12-0	2	0-7	2-10					0-7					
½	5-8	34-0	Str.												
½	3-11	11-9	Str.												
½	8-1	16-2	2	2-3	5-10										
½	8-9	17-6	2	2-7	6-2										
½	10-0	40-0	2	2-3	5-6					2-3					
½	11-4	45-4	2	2-7	6-2					2-7					
½	12-6	50-0	T-2	0-7	2-10	2-10	2-10	2-10		0-7					
½	15-2	60-8	T-2	0-7	3-6	3-6	3-6	3-6		0-7					
½	5-4	85-4	Str.												
½	3-3	26-0	Str.												
½	9-8	29-0	S-6	0-7	2-10	2-10	2-10			0-7					
½	11-0	33-0	S-4	0-7	3-2	3-6	3-2			0-7					
½	6-0	24-0	Str.												
½	5-0	20-0	Str.												
½	4-0	16-0	Str.												
½	8-6	68-0	Str.												
½	7-9	15-6	Str.												
½	5-9	11-6	Str.												
½	2-8		2	0-10	1-0					0-10					
½	7-0	14-0	Str.												
½	3-10	53-8	2	1-6	2-4										

Total ½"ϕ Steel in Structure Inlet = 1196'-9" = 799.43 #
Total Class "A" Concrete in Structure Inlet = 6.56 Cu. Yds.

STRUCTURE INLET DETAILS
WATERFLOW RETARDING STRUCTURE SITE NO. 7
PILOT AND SISTER GROVE CREEKS WATERSHED
OF THE
TRINITY RIVER WATERSHED
TEXAS
U.S. DEPARTMENT OF AGRICULTURE
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ROBERT M. SALTER - CHIEF
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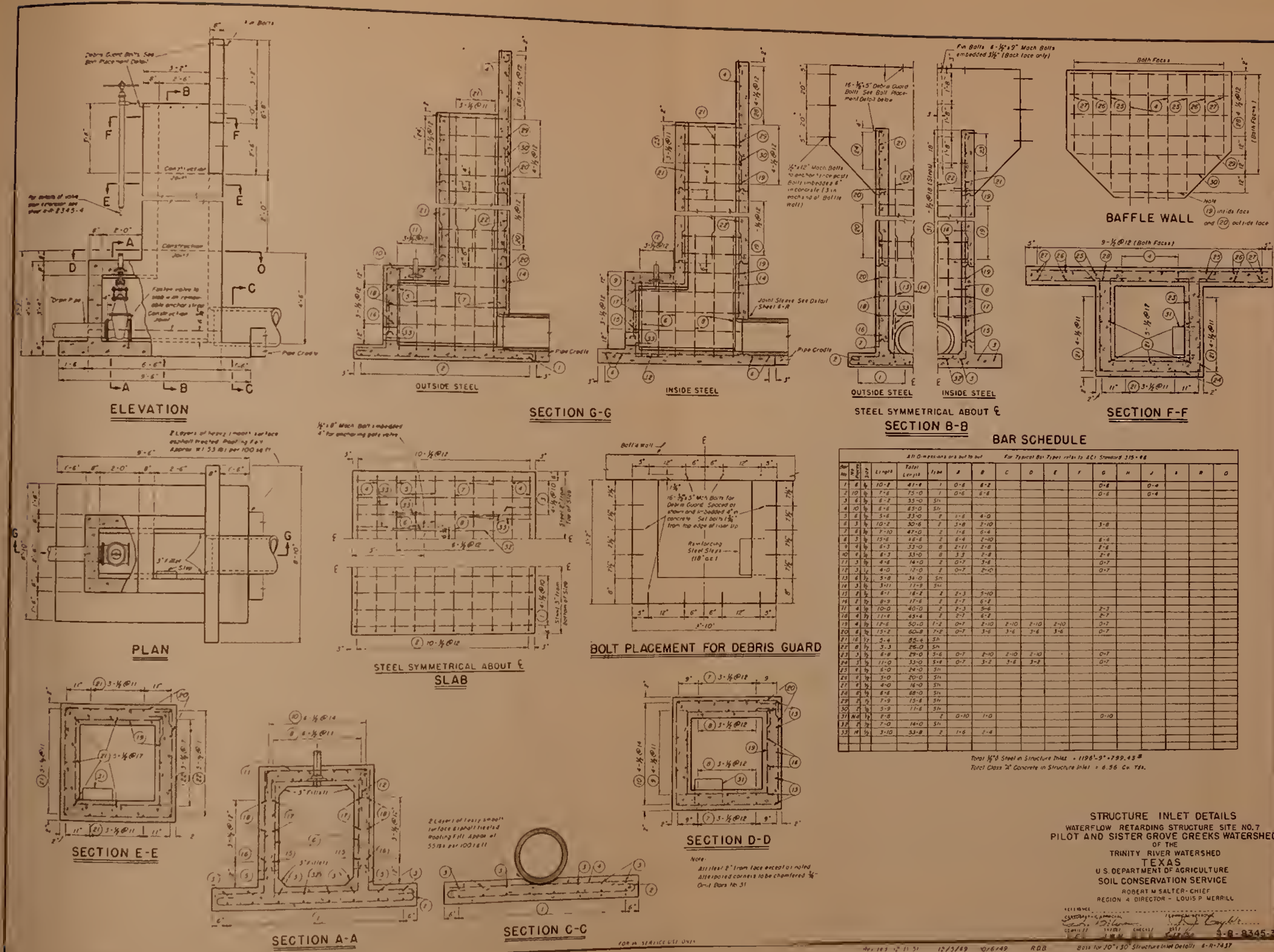
REFERENCE
CARTOGRAPHIC APPROVAL   TECHNICAL APPROVAL
COMPILED C.E.C.   TRACED J.W.M.   CHECKED C.E.C.   DATE 3-12-52   4-R-8345-3

AGR-SCS-FT. WORTH, TEX.

[R]evised 12-11-51   12/5/49   12/14/49   3/6/50   3/21/50   10/6/49   11/23/49   8/8/50   9/28/50   R.D.B.

Base for 30"x30" Structure Inlet Details 4-R-7437



BAR SCHEDULE

All Dimensions are out to out — For Typical Bar Types refer to ACI Standard 315-48

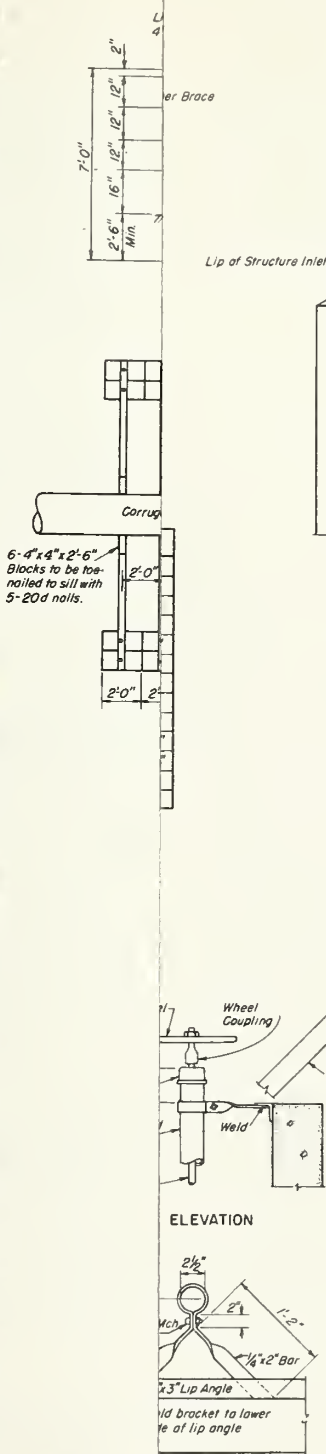
Bar No.	No. Req'd	Size	Length	Total Length	Type	A	B	C	D	E	F	G	H	J	K	R	O
1	6	½	10-8	41-4	1	0-6	6-2					0-6		0-4			
2	10	½	7-6	75-0	1	0-6	6-6					0-6		0-4			
3	6	½	6-2	33-0	Str												
4	10	½	6-6	65-0	Str												
5	6	½	5-6	33-0	2	1-6	4-0										
6	3	½	10-2	30-6	2	3-8	2-10					3-8					
7	6	½	7-10	47-0	2	1-6	6-4										
8	3	½	15-6	46-6	2	6-4	2-10					6-4					
9	4	½	8-3	33-0	8	2-11	2-8					2-6					
10	4	½	8-3	33-0	8	3-3	2-8					2-4					
11	3	½	4-8	14-0	2	0-7	3-6					0-7					
12	3	½	4-0	12-0	2	0-7	2-10					0-7					
13	6	½	5-8	34-0	Str												
14	3	½	3-11	11-9	Str												
15	2	½	8-1	16-2	2	2-3	5-10										
16	2	½	8-9	17-6	2	2-7	6-2										
17	4	½	10-0	40-0	2	2-3	5-6					2-3					
18	4	½	11-4	45-4	2	2-7	6-2					2-7					
19	4	½	12-6	50-0	1-2	0-7	2-10	2-10	2-10	2-10		0-7					
20	4	½	15-2	60-8	7-2	0-7	3-6	3-6	3-6	3-6		0-7					
21	16	½	5-4	85-4	Str												
22	8	½	3-3	26-0	Str												
23	3	½	8-8	29-0	5-6	0-7	2-10	2-10	2-10			0-7					
24	3	½	11-0	33-0	5-4	0-7	3-2	3-6	3-2			0-7					
25	4	½	6-0	24-0	Str												
26	4	½	5-0	20-0	Str												
27	4	½	4-0	16-0	Str												
28	8	½	8-6	68-0	Str												
29	2	½	7-9	15-6	Str												
30	2	½	5-9	11-6	Str												
31	Na	½	2-8		2	0-10	1-0					0-10					
32	2	½	7-0	14-0	Str												
33	14	½	3-10	53-8	2	1-6	2-4										

Total ½"∅ Steel in Structure Inlet = 1196'-9" = 799.45#
Total Class "A" Concrete in Structure Inlet = 6.56 Cu. Yds.

STRUCTURE INLET DETAILS
WATERFLOW RETARDING STRUCTURE SITE NO. 7
PILOT AND SISTER GROVE CREEKS WATERSHED
OF THE
TRINITY RIVER WATERSHED
TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL

4-R-8345-3

RGP SCS FT WORTH TEX



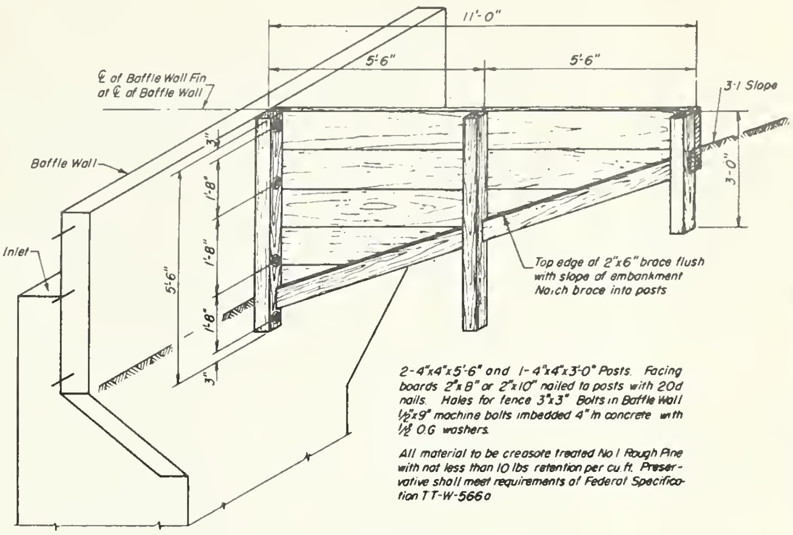
ELEVATION

PLAN

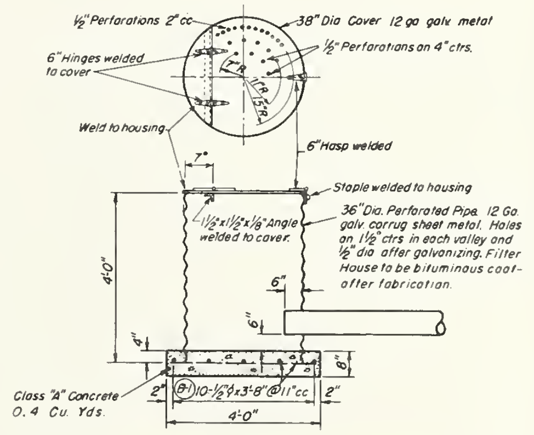
DETAIL A

ENSION

ve 12" Nipple. Coupling to
-¼" steel pins each end.



BAFFLE WALL FIN



INLET FILTER HOUSING

DETAILS
WATERFLOW RETARDING STRUCTURE SITE NO. 7
PILOT AND SISTER GROVE CREEKS WATERSHED
OF THE
TRINITY RIVER WATERSHED
TEXAS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL

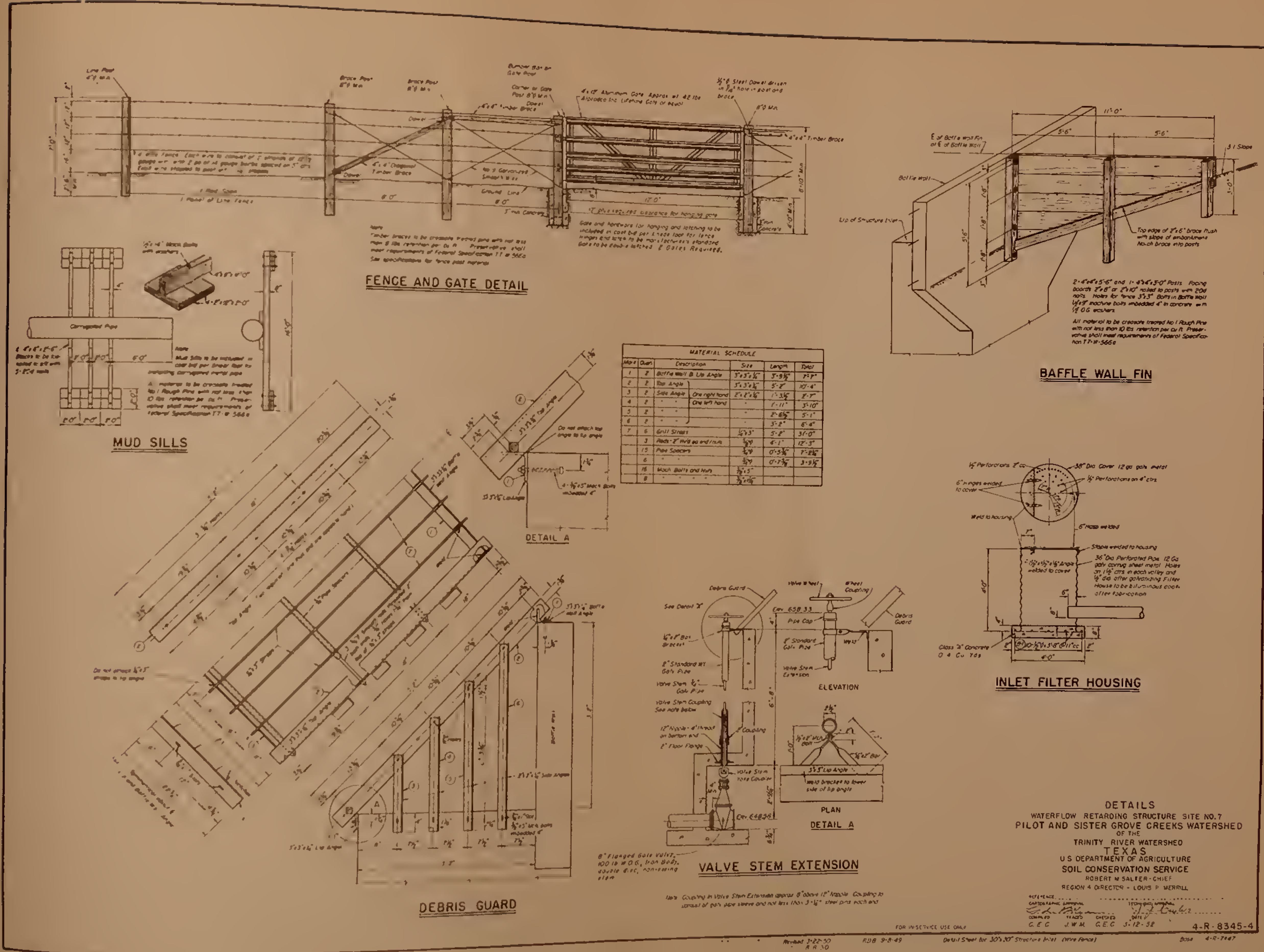
REFERENCE
CARTOGRAPHIC APPROVAL — TECHNICAL APPROVAL

COMPILED	TRACED	CHECKED	DATE
C. E. C.	J. W. M.	C. E. C.	3-12-52

FOR IN-SERVICE USE ONLY

4-R-8345-4

AGR-SCS-FT. WORTH, TE -22-50 -8-50 RDB 9-8-49 Detail Sheet for 30"x30" Structure Inlet (Wire Fence) Base 4-R-7447



MATERIAL SCHEDULE

Mark	Quan.	Description		Size	Length	Total
1	2	Baffle Wall & Lip Angle		3"x3"x1/4"	3'-9 1/2"	7'-7"
2	2	Top Angle		3"x3"x1/4"	5'-2"	10'-4"
3	2	Side Angle	One right hand	2"x2"x1/4"	1'-3 1/2"	2'-7"
4	2	" "	One left hand	"	1'-11"	3'-10"
5	2	" "		"	2'-6 1/2"	5'-1"
6	2	" "		"	3'-2"	6'-4"
7	6	Grill Strap		1/4"x3"	5'-2"	31'-0"
	3	Rods - 2" thrd ea end / nuts		3/4"Ø	4'-1"	12'-3"
	15	Pipe Spacers		1/4"Ø	0'-5 3/4"	7'-2 1/4"
	6	" "		1/4"Ø	0'-7 1/2"	3'-9 1/2"
	18	Mach. Bolts and Nuts		1/2"x5"		
	8	" " " "		1/2"x6 1/2"		

APPENDIX VI

PROGRAM APPRAISAL

The recommended program will reduce damage caused by floodwater and sediment, increase the value of production from certain flood plain lands and increase the income from treated uplands. These reductions in damages and increases in income are the benefits from the recommended program. The purpose of this appendix is to set forth the monetary evaluations of the benefits accruing from the recommended program and components thereof and to compare these benefits with the cost of the recommended program or of the applicable component part or group of measures.

The annual benefit reported does not include the benefits resulting from the application of measures which are to be installed by the going program.

REDUCTION OF DAMAGE FROM FLOODWATER AND SEDIMENT

Reduction in Floodwater Damage

Acres Damaged: Floodwater damage occurs on about 183,665 acres of bottomland in the San Antonio River Watershed. This area does not include bottomland areas within the city of San Antonio and the area (2.4 miles in length) in the city of Kenedy on which works of improvement have been recommended by the Corps of Engineers. Each year an average of about 59,393 acres are flooded, which includes the repetition of acreages flooded more than once during the year. The recommended program will reduce the average annual total acreage flooded to about 32,261 acres, or a reduction of about 45.7 percent. The average depth of inundation on remaining areas subject to flooding also will be reduced.

Crops and Pasture Damage Reduction: At 1950 prices it is estimated that installation of the recommended program will result in an average annual benefit of $89,322 of which $27,890 will result from the application of the land treatment and stabilizing measures and $61,432 from the installation of floodwater retarding structures. Reduction of damages to crops and pasture will amount to approximately 28.3 percent of all benefits derived from reduction in floodwater and sediment damage.

Flood Plain Scour Damage Reduction: It is estimated that the recommended program will reduce flood plain scour damage $34,244 annually, or approximately 10.8 percent of the total benefits from reduction in damages. The application of land and stabilizing treatment measures will account for $11,626 of this benefit and the installation of floodwater retarding structures $22,618.

Other Agricultural Damage Reduction: It is estimated that the recommended program will reduce average annual damage to fences, livestock, farm buildings, stored crops, private farm roads and similar items

$105,160, or approximately 33.3 percent of the total benefits from reduction of damages. A benefit of $31,453 will result from the application of land treatment and stabilizing measures and $73,707 from the installation of floodwater retarding structures.

Nonagricultural Damage Reduction: The recommended program is estimated to reduce average annual damages to highways, bridges, roads, railroads, urban and other nonagricultural property $48,783, or approximately 15.4 percent of the total benefits from reduction of damages. A benefit of $15,168 will result from the application of the land treatment and stabilizing measures and $33,615 from the installation of floodwater retarding structures.

Reduction of Sediment Damage

Valley Sedimentation: The value of the estimated reduction in valley sedimentation resulting from the recommended program will be $5,748 annually, or approximately 1.8 percent of the total benefits from reduction of damages. A benefit of $2,058 will result from the application of land treatment and stabilizing measures and $3,690 from the installation of floodwater retarding structures.

Reservoir Sedimentation: It is estimated that the average annual benefit obtained from reduction of sedimentation in Medina reservoir will be $355, or approximately 0.1 percent of the total benefits from reduction of damages. This benefit will result from the application of land treatment and stabilizing measures.

Reduction of Indirect Damage

The value of the benefit from reduction of losses to business, labor earnings and other phases of community life will be approximately $32,482 annually, or 10.3 percent of total benefits from reduction of damages. A benefit of $9,940 will result from the application of land treatment and stabilizing measures and $22,542 from the installation of floodwater retarding structures.

The benefits from reduction of floodwater, sediment and indirect damages are summarized in table 45. Summaries are also included in table 48 for creek watersheds of the San Antonio River Watershed.

INCREASED INCOME FROM THE RECOMMENDED PROGRAM

The recommended program will not only reduce damages from floodwater and sediment but also will increase the productivity of the watershed and the agricultural income.

Intensification of Land Use in Flood Plain

The increase in net annual income from flood plain lands on which the agricultural use is expected to be intensified, after protection

Table 45. Summary of Average Annual Benefits, 1950 Prices, from Reduction of Floodwater and Sediment Damages by the Recommended Program

San Antonio River Watershed, Texas

Item	Land Treatment and Stabilizing Measures	Floodwater Retarding Structures	Recommended Program	Floodwater Retarding Structures Only 1/
	(dollars)	(dollars)	(dollars)	(dollars)
Reduction in Floodwater Damage				
Crops and Pasture	27,890	61,432	89,322	75,890
Flood Plain Scour	11,626	22,618	34,244	28,849
Other Agricultural	31,453	73,707	105,160	100,271
Nonagricultural	15,168	33,615	48,783	46,333
Subtotal	86,137	191,372	277,509	251,343
Reduction in Sediment Damage				
Valley Sediment Deposition	2,058	3,690	5,748	4,666
Reservoir Sediment Deposition	355	-	355	-
Subtotal	2,413	3,690	6,103	4,666
Reduction in Indirect Damage	9,940	22,542	32,482	29,351
TOTAL	98,490	217,604	316,094	285,360

1/ The benefit shown is present damages less damages in the future with only structures installed.

from flooding, is estimated at $114,551; all of which will result from the installation of floodwater retarding structures.

Indirect Benefits from Intensified Land Use: Increased production in the protected flood plains will contribute to the economic life of the nearby communities through increased business, added income to workers in agricultural processing or servicing establishments, and in other similar ways. Such benefits were not included in the benefit-cost evaluation.

Conservation Benefits

Reduction in Soil Loss: In estimating the effects of the recommended program on soil losses, applicable research data of experiment stations in Texas and Oklahoma and information developed in the conservation needs study 1/ were used.

The percentage of physical reductions in soil loss, due to the recommended program is shown by creek watersheds in table 46.

Farm Income: Changes in land use and increases in yields under the recommended program will result in an average annual benefit (through increased receipts or decreases in expenses) of $5,854,056 annually. Operating costs (decreased receipts and increased expenses) will be $1,609,354 annually. In addition, land owners and operators will be expected to expend the equivalent of $282,676 annually for the application and maintenance of the land treatment and stabilizing measures.

Effect of the Recommended Program on Farm and Ranch Operating Units: The following three adjustments normally take place on all farm and ranch operating units: (1) Retirement of some land from cultivation to pasture, (2) installation of suitable mechnical structures and vegetative adjustments on cropland and grassland, and (3) adjustments in livestock numbers on grassland in accordance with long-time range grazing capabilities.

These adjustments and measures involve limited organization changes. Substantial crop and pasture yield increases will result from the program, with a corresponding increase in livestock numbers in all the problem areas in soil conservation.

The benefit to be expected will exceed the cost of the program to land owners and operators in all the problem areas in soil conservation.

LOSS OF NET INCOME

The annual loss of net income in the pool areas of floodwater retarding structures was determined for each sample watershed where

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1/ Made by the Soil Conservation Service in 1949.

Table 46. Estimated Percentage Reduction in Annual Soil Loss Due to the Recommended Land Treatment and Stabilizing Measures

San Antonio River Watershed, Texas

Creek or Section of River Watersheds	Percent Reduction in Annual Soil Loss
Upper San Antonio	28.2
Lower San Antonio	28.1
Upper Cibolo	19.5
Lower Cibolo	27.4
Upper Medina	18.4
Lower Medina	25.8
Ecleto Creek	27.3

retarding structures were recommended. Interest at rates of four and two and one-half percent were applied to the costs of privately owned sites and publicly acquired sites, respectively. Water values were calculated by multiplying one-half of the permanent pool capacity in acre-feet by a nominal value ($1.00) per acre-foot. The value of the water impounded and interest on the cost of site acquisition were deducted from the loss in income.

The annual loss in net income, after deduction of interest and water values, was added to the other costs of floodwater retarding structures and totaled $18,719 (1950 prices) for the watershed.

NON-MONETARY BENEFITS

Values were not placed upon such benefits as enhancement of recreational values, increased food and improved shelter for wild fowl and game animals, improved public health, and increased security from flood hazards. These items, although they are significantly affected by reduction of flooding and are highly important in the economy of the watershed, are not accurately measureable in monetary terms.

COMPARISON OF BENEFIT AND COST

The average annual cost of the recommended program is $2,197,401. Installation costs of the recommended program, other than the construction costs of floodwater retarding structures, were converted to annual costs by using a two and one-half percent interest rate for public costs and a four percent interest rate for private costs. The construction costs of floodwater retarding structures were amortized over a 75-year period using the same interest rates as above. Table 39, Appendix V and table 47 set forth the cost distribution.

The average annual benefit from the recommended program will be $6,284,701 at 1950 prices, of which $5,854,056 will be conservation benefits to land owners and operators. The benefits are summarized by groups of measures and by creek and sections of river watersheds in table 48. Damage estimates from which these estimates of benefits are derived are summarized in table 35, Appendix IV.

Adjustment of Prices from 1950 to a Predicted Price Level

Estimates of damages and benefits in this appendix have been made on the basis of prices in 1950, the latest full calendar year for which prices were available. Since 1950 was a year in which prices were undergoing considerable adjustment, the 1950 benefits and costs herein have been factored for the purpose of comparing benefits and costs of the recommended program at a predicted normal, based on an assumed high level of employment. The factors were determined and used as follows:

Table 47. Estimated Annual Costs of the Recommended Program (1950 Prices)

San Antonio River Watershed, Texas

Measure	Annual Operation and Maintenance After Installation			Annual Equivalent of Installation Cost			Total Average Annual Cost			Total
		Non-Federal			Non-Federal			Non-Federal		
	Federal	Public	Private	Federal	Public	Private	Federal	Public	Private	
	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Land Treatment and Stabilizing Measures										
Terraces	-	-	185,640	26,266	-	32,228	26,266	-	217,868	244,134
Field Diversions	-	-	3,393	1,920	-	1,442	1,920	-	4,835	6,755
Cover Crops	-	-	-	878	-	1,832	878	-	1,832	2,710
Farm and Group Waterways	-	-	5,884	1,949	-	2,118	1,949	-	8,002	9,951
Establishment of New Grassland	-	-	-	1,111	-	9,322	1,111	-	9,322	10,433
Improvement and Management of Existing Grassland	-	-	5,475	12,367	-	35,342	12,367	-	40,817	53,184
Technical Services	-	-	-	31,602	-	-	31,602	-	-	31,602
Educational Assistance	-	-	-	3,003	3,003	-	3,003	3,003	-	6,006
Administration of Direct Aids	-	-	-	3,599	-	-	3,599	-	-	3,599
Facilitating Measuring Devices	4,425 1/	-	-	539	-	-	4,964	-	-	4,964
Independent Measures										
Floodwater Retarding Structures	-	17,000	18,719 2/	163,237	20,717	-	163,237	37,717	18,719	219,673
Increased Operating Cost to Farm Operators	-	-	1,609,354	-	-	-	-	-	1,609,354	1,609,354

1/ Annual equivalent of 15 years Operation and Maintenance.

2/ Annual loss in net income in structure sites.

Table 48. Summary of Annual Benefits, 1950 Prices, from the Recommended Program, by Creek and Section of River Watersheds

San Antonio River Watershed, Texas

Creek and Section of River Watershed and Type of Benefit	Land Treatment and Stabilizing Measures	Floodwater Retarding Structures	Recommended Program	Floodwater Retarding Structures Only
	(dollars)	(dollars)	(dollars)	(dollars)
San Antonio River Watershed				
Reduction of Damages	98,490	217,604	316,094	285,360
Intensified Use of Flood Plain Lands	-	114,551	114,551	114,551
Conservation Benefits	5,854,056	-	5,854,056	-
Grand Total	5,952,546	332,155	6,284,701	399,911
Upper San Antonio				
Reduction of Damages	15,145	43,572	58,717	58,615
Intensified Use of Flood Plain Lands	-	34,409	34,409	34,409
Conservation Benefits	1,681,088	-	1,681,088	-
Main Stem Benefits 1/	7,423	12,509	19,932	15,084
Total Benefits	1,703,656	90,490	1,794,146	108,108
Lower San Antonio				
Reduction of Damages	4,758	21,451	26,209	25,017
Intensified Use of Flood Plain Lands	-	26,602	26,602	26,602
Conservation Benefits	1,296,280	-	1,296,280	-
Main Stem Benefits 1/	8,002	5,787	13,789	7,034
Total Benefits	1,309,040	53,840	1,362,880	58,653
Upper Medina				
Reduction of Damages	977	- 2/	977	- 2/
Intensified Use of Flood Plain Lands	-	-	-	-
Conservation Benefits	176,222	-	176,222	-
Main Stem Benefits 1/	-	-	-	-
Total Benefits	177,199	0	177,199	0

Table 48 (continued). Summary of Annual Benefits, 1950 Prices, from the Recommended Program, by Creek and Section of River Watersheds

San Antonio River Watershed, Texas

Creek and Section of River Watershed and Type of Benefit	Land Treatment and Stabilizing Measures	Floodwater Retarding Structures	Recommended Program	Floodwater Retarding Structures Only
	(dollars)	(dollars)	(dollars)	(dollars)
Lower Medina				
Reduction of Damages	8,298	11,378	19,676	17,125
Intensified Use of Flood Plain Lands	-	5,402	5,402	5,402
Conservation Benefits	985,225	-	985,225	-
Main Stem Benefits 1/	3,595	3,692	7,287	2,910
Total Benefits	997,118	20,472	1,017,590	25,437
Upper Cibolo				
Reduction of Damages	265	- 2/	265	- 2/
Intensified Use of Flood Plain Lands	-	-	-	-
Conservation Benefits	112,835	-	112,835	-
Main Stem Benefits 1/	2,304	-	2,304	-
Total Benefits	115,404	0	115,404	0
Lower Cibolo				
Reduction of Damages	38,284	90,747	129,031	127,222
Intensified Use of Flood Plain Lands	-	29,176	29,176	29,176
Conservation Benefits	1,149,075	-	1,149,075	-
Main Stem Benefits 1/	4,526	6,176	10,702	8,312
Total Benefits	1,191,885	126,099	1,317,984	164,710
Ecleto				
Reduction of Damages	2,687	16,604	19,291	19,366
Intensified Use of Flood Plain Lands	-	18,962	18,962	18,962
Conservation Benefits	453,331	-	453,331	-
Main Stem Benefits 1/	2,226	5,688	7,914	4,675
Total Benefits	458,244	41,254	499,498	43,003

1/ Main stem benefits allocated back to creek and section of river watersheds.

2/ Floodwater retarding structures not recommended at this time.

1. A standard prices-received-by-farmers factor for each crop and for livestock was obtained by division of the predicted normal level index by the corresponding 1950 index. The factors thus obtained were applied to 1950 values of all commodities produced in calculating conservation benefits through increased farm receipts and in calculating operating costs through decreased farm receipts.

2. The prices-received-by-farmers index was developed for each sample watershed by weighting the 1950 index for each commodity by the quantity produced in each sample watershed. A corresponding predicted normal index was developed for each sample watershed and the factor derived by division of the normal index by that for 1950 was used in adjusting the crop and pasture damage and the damage from flood plain scour. It was also used for measuring the benefits from more intensified use of flood plain lands.

3. The standard used for prices paid for items used in production by farmers was an index of 246 (1910 - 14 = 100) for 1950. The index of the predicted level of 205 (1910 - 14 = 100). Therefore, 205/246 or 0.8333 was the factor used to adjust 1950 prices to the predicted level. This factor was applied to Other Agricultural Damages, to private costs of installation and maintenance of the recommended program and to costs of farm and ranch operation.

4. The standard used for construction costs was the Engineering News Record index for 1950 which was 513 (1913 = 100); the index of the predicted level was 424. Therefore, 424/513 or 0.8265 was the factor used to adjust 1950 prices to the predicted level. This factor was applied to all benefits derived from a reduction in damage to nonagricultural property and in adjusting construction costs of the flood prevention measures to normal prices.

5. The standard used for indirect damages was an index of 425 for wage rates in 1950. The index of the predicted level was 360; therefore, 360/425 or 0.8471 was the factor used in adjusting indirect damages to predicted normal prices.

6. It was believed that Federal salaries and travel costs would decline less than ordinary wage rates so a factor of 0.9235 was used to reduce the costs of technical services to the predicted normal level. This represents one-half of the predicted decline in wage rates.

Comparison of Average Annual Benefit and Cost

Comparison of the average annual benefit with the average annual cost of the recommended program under normal prices provides the economic evaluation of the program.

The ratio between the benefit ($4,673,491) and cost ($1,650,889) of the land treatment measures is 2.83:1.00. The ratio for the floodwater retarding structures of $255,567 benefit and cost of $179,284 is 1.43:1.00. The ratio for the entire recommended program of $4,929,058 benefits to $1,834,705 costs is 2.69:1.00. A summary and comparison of benefit-cost ratios of the recommended program is shown in table 49.

Comparison of the Effect of Discounting Delayed Benefits and Costs

There are certain types of benefits and costs resulting from the recommended program which will be delayed until treatment measures become fully effective. In this analysis, therefore, such benefits and costs were discounted to allow for this lag in effectiveness.

Discounting Benefits and Costs of the Recommended Program: It was assumed that benefits from intensified use of flood plains, conservation benefits and floodwater damage reductions resulting from the application of land treatment and stabilizing measures, would be delayed an average of five years. A similar delay would be applicable to farm and ranch operating costs. It was also assumed that each of these benefits and costs would start at zero and build up uniformly to the maximum over the period of delay. They would then level off and remain constant thereafter.

Benefits Not Discounted: Benefits from reductions in damage resulting from the installation of floodwater retarding structures will become fully effective immediately upon installation and therefore, were not discounted.

Effect of Discounting: Discounting deferred benefits and costs from recommended land treatment and stabilizing measures decrease their benefit-cost ratio (normal prices) from 2.83:1 to 2.79:1. The benefit-cost ratio for floodwater retarding structures is reduced from 1.43:1 to 1.41:1. The benefit-cost ratio for the recommended program decreases from 2.69:1 to 2.65:1.

METHODS OF DETERMINING VALUE OF ANNUAL BENEFITS FROM REDUCTIONS IN FLOOD AND SEDIMENT DAMAGE

Floodwater and sediment damages were calculated under conditions which will prevail before and after the installation of each group of measures of the recommended program, as described in Appendix IV. The difference in annual damages at the time of initiation of a group of measures and those expected after its installation constitute the benefit of that group from reduction of damage.

Benefits from reduction of crop and pasture, other agricultural and road and bridge damage were estimated from the combined effects of reduction in area inundated and in depth of inundation. No benefits were estimated for pool areas of recommended floodwater retarding structures.

Table 49. Summary and Comparison of Benefit-Cost Ratios of the Recommended Program

San Antonio River Watershed, Texas

Creek or Section of River Watershed	1950 Prices: Land Treatment and Stabilizing Measures	1950 Prices: Floodwater Retarding Structures	1950 Prices: Recommended Program	1950 Prices: Floodwater Retarding Structures Only	Normal Prices: Land Treatment and Stabilizing Measures	Normal Prices: Floodwater Retarding Structures	Normal Prices: Recommended Program	Normal Prices: Floodwater Retarding Structures Only
	(dollars benefit per $1.00 cost)				(dollars benefit per $1.00 cost)			
Upper San Antonio	3.06	1.28	2.86	1.52	2.88	1.28	2.71	1.53
Lower San Antonio	3.06	1.10	2.86	1.20	2.88	0.99	2.69	1.09
Upper Medina	2.38	1/	2.38	1/	2.13	1/	2.13	1/
Lower Medina	3.00	1.49	2.94	1.85	2.82	1.64	2.77	2.01
Upper Cibolo	2.61	1/	2.61	1/	2.40	1/	2.40	1/
Lower Cibolo	3.06	2.47	2.99	3.23	2.90	2.18	2.82	2.93
Ecleto	2.99	1.18	2.65	1.23	2.82	1.08	2.51	1.13
Total Watershed	3.01	1.51	2.86	1.82	2.83	1.43	2.69	1.74

1/ Floodwater Retarding Structures not recommended at this time.

Benefit from reduction of sediment damage to Medina reservoir was calculated from an estimate of the reduction in the quantity of sediment that would be deposited annually, Appendix IV. It was estimated that the deposition in Medina Lake would be reduced 10.2 acre-feet annually by the recommended program. This is a reduction of approximately 4 percent and the benefit from installation of the recommended program would be $8,894 x 0.04 or $355.

Benefits from the reduction of crop and grassland damage, valley sediment damage, flood plain scour damage, other agricultural, nonagricultural damage to county roads and indirect damage derived from each group of measures were determined directly by analysis of sample watersheds. Expansion to other areas was carried out as discussed in Appendix IV. Other benefits from reduction of damage were evaluated on a creek watershed or a section of the river watershed basis.

Table 50 shows the average annual benefit from reduction of damage in the Calaveras Creek sample watershed and table 51 gives similar information for the Lower Medina River Watershed.

The benefits by creek watersheds were added to obtain the total for the watershed, table 45.

Method of Determining Benefits on the Main Stem

Benefits from the reduction of crop and grassland damage, flood plain scour damage, other agricultural damage, valley sediment damage, nonagricultural and indirect damage derived from each group of measures were determined directly by analysis of main stem stream reaches (Appendix III). These benefits were then prorated back to the creek watersheds on a percentage basis in proportion to their contribution to flood flows. Table 48 shows a summary of main stem benefits prorated to creek or section of river watersheds.

METHODS OF DETERMINING ANNUAL BENEFIT FROM INTENSIFIED USE OF THE FLOOD PLAIN

More intensive agricultural use of bottomland soils will be made possible by the reductions in extent and frequency of flooding resulting from the recommended floodwater retarding structures. More intensive agricultural use will be possible on two general types of areas.

The first type consists of the flood plains of small creeks below floodwater retarding structures, which will receive a high degree of protection from flooding. A large percentage of such areas will become suitable for more intensive use. The second type consists of portions of the flood plain along those larger tributaries where a substantial degree of protection will be provided.

Present flood plain use was determined by detailed investigation of sample watersheds. The location and extent of the areas which would

Table 50. Summary of Benefits from Reduction of Flood Damages, 1950 Prices, Calaveras Creek Sample Watershed

San Antonio River Watershed, Texas

Sample and Source of Benefit	From Recommended Land Treatment and Stabilizing Measures	From Floodwater Retarding Structures	Total
	(dollars)	(dollars)	(dollars)
Calaveras Creek			
Crops and Pasture	655	2,338	2,993
Flood Plain Scour	402	1,213	1,615
Other Agricultural	1,153	4,581	5,734
Nonagricultural	491	2,230	2,721
Valley Sediment	57	172	229
Indirect	317	1,211	1,528
Main Stem	1,213	4,776	5,989
TOTAL	4,288	16,521	20,809

Table 51. Summary of Benefits from Reduction of Flood Damages, 1950 Prices, Lower Medina River Watershed 1/

San Antonio River Watershed, Texas

Sample Watershed and Source of Benefit	From Recommended Land Treatment and Stabilizing Measures	From Floodwater Retarding Structures	Total
	(dollars)	(dollars)	(dollars)
Calaveras Creek 2/			
Crops and Pasture	962	2,265	3,227
Flood Plain Scour	590	1,175	1,765
Other Agricultural	1,694	4,438	6,132
Nonagricultural	721	2,160	2,881
Valley Sediment	84	167	251
Indirect	466	1,173	1,639
Total	4,517	11,378	15,895
Salado Creek 2/			
Crops and Pasture	537	-	537
Flood Plain Scour	212	-	212
Other Agricultural	1,094	-	1,094
Nonagricultural	1,398	-	1,398
Valley Sediment	34	-	34
Indirect	393	-	393
Total	3,668	-	3,668
Cibolo Creek 2/			
Crops and Pasture	43	-	43
Flood Plain Scour	5	-	5
Other Agricultural	35	-	35
Nonagricultural	20	-	20
Valley Sediment	-	-	-
Indirect	10	-	10
Total	113	-	113
Creek Watershed Total			
Crops and Pasture	1,542	2,265	3,807
Flood Plain Scour	807	1,175	1,982
Other Agricultural	2,823	4,438	7,261
Nonagricultural	2,139	2,160	4,299
Valley Sediment	118	167	285
Indirect	869	1,173	2,042
Total	8,298	11,378	19,676

1/ Source of data: Table 34, Appendix IV.

2/ Sample watersheds used in expansion.

be suitable for more intensive use after installation of floodwater retarding structures were determined in the following manner:

1. Hydrologic analysis of the effect of the installations on frequency of flooding.

2. Study of soil conservation survey data to ascertain the suitability of protected lands for more intensive use.

3. Land owners and operators in the sample watersheds were interviewed to determine what changes in land use they would make if flood protection were provided.

The increased intensity of land use to be expected on the protected areas is as follows:

1. Most of the present meadow and idle land would be used for cropland.

2. Portions of the land now used for pasture would be converted to cropland.

3. Portions of the woodland now used for pasture would be cleared and developed into improved pasture and cropland.

It was assumed that the percentages of cropland used for various crops would be approximately the same as at present. It was assumed that intensification of land use would be confined to the portion of the flood plain which would be flooded less frequently than once in three years after installation of the recommended program. As an example, in Calaveras Creek Watershed it is expected that 15 percent of the pasture would be converted to cropland while in Escondido and Santa Clara Creeks 40 percent and 12 percent, respectively, were considered the amounts which would be converted.

In the calculation of benefits the average annual gross value of the production in the area protected was determined both for present land use and for future conditions, assuming that no changes would occur in the per acre yields. Costs of production were based on experiment station data including all machinery expense, labor (whether performed by the operator and his family or by hired labor) and an added charge for taxes. Overhead and clearing costs were deducted from the gross return to obtain the net increase in value of annual production. The expected annual damage by floods to the increased damageable value after installation of the recommended program was deducted from the net income in determining the net benefit. The net benefit was multiplied by the appropriate conversion factor for the area to determine the benefit under predicted normal price levels.

METHOD OF DETERMINING CONSERVATION BENEFITS

The land treatment and stabilizing measures of the recommended program will be applied to the agricultural land in the San Antonio River

Watershed. Since approximately 96.5 percent of the total acreage is operated under a farm or ranch economy, the effect that the program will have on agricultural income must be considered. A comparison of the crop and grassland production and agricultural income from each problem area in soil conservation was made for the future with the recommended program and for the future without treatment to facilitate the evaluation of the effects of the program.

The differences in net income and cost revealed by this analysis, including the cost of installation and maintenance of the measures, serve as the basis for determining conservation benefit and cost of the land treatment and stabilizing measures. An increase in gross income or a reduction in cost, resulting from land treatment and stabilizing measures was regarded as a benefit. If application of the remedial program resulted in reduced gross income or increased cost, the difference was classed as a cost.

Present Crop Yields: The present crop yields used in this report are based on field information obtained from farmers and ranchers and qualified agricultural technicians, and on data from agricultural publications.

Present Yields and Future Yields Without Land Treatment Measures: Improved seed, mechanization, increased emphasis upon soil improving practices and the selection of high-yielding land for cotton production have distorted the normal trends of crop yields in the watershed. Usual methods of yield analysis based on acreage and production show sharp upward trends in the yields of various crops and sharp downward trends in others.

In order to relate the productivity of the watershed to the physical condition of the farm lands, the results of the soil decline study made by the Soil Conservation Service were used. Land capability classes are closely related to the crop-producing ability of the remaining soil and it can be expected that crop productivity will decline at a rate comparable with the rate at which soil losses are occurring. However, when continuing soil losses so reduce the productivity of the soil that it is no longer economical to produce the usual cultivated crops, it can be assumed that the land will cease to be used for crop production.

As an example, in a large portion of the Blackland Prairie problem area in soil conservation the present average depth of remaining topsoil on cultivated lands is approximately 8 inches. This type of land has a present average capability of Class III and is therefore suitable for use as cultivated cropland if complex and intensive conservation measures are applied. Under present cropping systems this soil is being eroded at the rate of 1-1/2 inches in 15 years. When the remaining topsoil depth is reduced to about 3 inches, this kind of land will reach such a low state of productivity that its most profitable use would be for either grass or hay crops. The yield trend in the future without land treatment was assumed to approximate the trend or rate of soil losses.

Although yields in the future will decline without land treatment, for evaluation purposes no further decline was considered after the period of installation. This resulted in a conservative estimate of the difference between yields in the future without treatment and with treatment. This assumption also eliminated the need for the difficult adjustment of the lower portion of the trend line to reflect the factors of forced changes in crop and cultural practices. The trend of future cotton yields which can be expected under present crop production practices for the Blackland Prairie is shown in figure 43.

Future Yields with Land Treatment and Stabilizing Measures: All available evidence on the effect of land treatment on yields was related to similar conditions in the watershed. Several hundred historical yield records 1/ were studied from farm units in similar problem areas in soil conservation, which showed the effect of land treatment and stabilizing measures. These records covered a period of from 2 to 6 years of treatment application and maintenance and indicated the effects which could be expected. It was recognized that these records may have included some increases due to superior management on these farms, and the reported increases were adjusted downward in cases when they seemed unusually high.

In a study 2/ conducted by the University of Illinois Agricultural Experiment Station in cooperation with the Soil Conservation Service a comparison was made between contour cultivation and up-and-down slope cultivation on the same farm. The effects of management, equipment and soils were eliminated as far as possible in this study.

The advantage in yield due to contour cultivation alone was reported to be 12 percent for corn, 16 percent for oats and 17 percent for wheat. As these increases were the result of the application of a single practice it was considered that the yield increases as shown in table 52 are conservative and reasonable.

The amount of increase shown by these records can be expected within a period of 5 years. By the fifth year after application, most land treatment measures should have reached their maximum effectiveness. The percentages of increase shown in the study referred to were applied to present yields to determine the future expected yield of the various crops. Both present and future yields of the various crops are shown in table 52.

Pasture Yields: A study was made of grassland in each problem area in soil conservation in the San Antonio River Watershed. Trends of future production with and without the application of the recommended program were determined.

1/ Effects of Soil Conservation Practices on Production, Region IV, Soil Conservation Service, USDA, Fort Worth, Texas.

2/ Sauer, F. L. "Methods of Evaluating Soil Conservation Measures," page 655, Journal of Farm Economics, February, 1949.

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
ROBERT M. SALTER-CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL-REGIONAL DIRECTOR

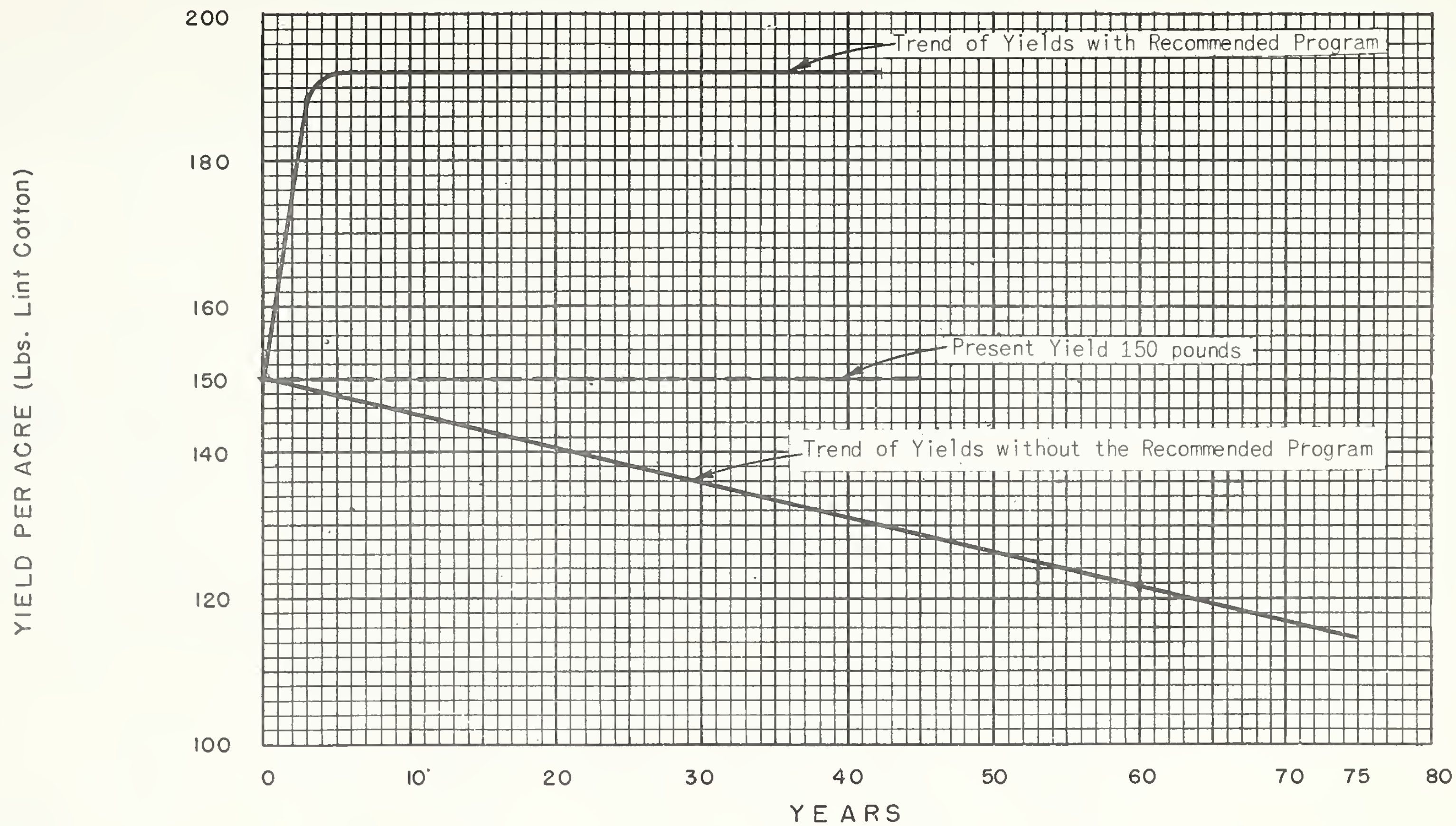


Figure 43

COTTON YIELD TRENDS IN THE FUTURE
WITH AND WITHOUT THE RECOMMENDED PROGRAM
RIO GRANDE PLAIN PROBLEM AREA IN SOIL CONSERVATION

SAN ANTONIO RIVER WATERSHED
TEXAS

Source: Soil Dectine Study and Records
Soil Conservation Service

4/25/52 4-N-8222-42

Table 52. Estimated Present Crop and Pasture Yields Per Acre and Future Yields With and Without the Recommended Land Treatment and Stabilizing Measures

San Antonio River Watershed, Texas

Crop	Unit	Present	Future Treated	Future Untreated	Present	Future Treated	Future Untreated	Present	Future Treated	Future Untreated
		Rio Grande Plain			Edwards Plateau			Blackland Prairie		
Corn	Bu.	17.00	25.50	14.50	13.80	17.30	12.50	24.00	33.10	18.50
Cotton	Lb.	150.00	192.00	143.00	-	-	-	165.00	200.00	152.50
Grain Sorghum	Bu.	20.50	26.60	17.50	17.40	21.00	16.20	27.80	31.40	21.50
Forage Sorghum	Ton	1.60	2.08	1.35	1.20	1.45	1.08	1.70	1.92	1.30
Peanuts	Lb.	454.40	681.60	390.40	-	-	-	-	-	-
Oats	Bu.	18.80	21.60	16.00	20.10	20.70	18.20	23.00	25.30	17.80
Flax	Bu.	7.30	8.80	6.20	-	-	-	-	-	-
Wild Hay	Ton	1.00	1.30	0.85	0.90	1.08	0.82	1.00	1.27	0.77
Pasture	AUMG 1/	0.40	0.75	0.40	0.60	0.80	0.60	0.60	1.00	0.60
		Forested Coastal Plain			Coast Prairie					
Corn	Bu.	14.90	17.90	13.50	25.00	28.00	23.00			
Cotton	Lb.	138.00	179.40	128.00	200.00	220.00	194.00			
Grain Sorghum	Bu.	18.90	22.70	15.70	31.20	35.90	28.80			
Forage Sorghum	Ton	1.40	1.68	0.90	2.20	2.53	2.04			
Peanuts	Lb.	342.40	460.80	224.00	-	-	-			
Oats	Bu.	-	-	-	30.00	31.50	27.70			
Flax	Bu.	-	-	-	8.00	9.20	7.40			
Wild Hay	Ton	0.90	1.13	0.60	1.25	1.85	1.00			
Pasture	AUMG 1/	0.40	0.80	0.40	1.00	1.50	1.00			

1/ Animal Unit Months of grazing per year.

The present average grazing capacity or safe stocking rate expressed in animal unit months of grazing and a future rate without the recommended program was developed for each area. These data were based on estimates of range specialists and information from field technicians. Since range and pasture deterioration is slow, no change was shown between present grazing capacity estimates and future grazing capacity without the recommended program. Table 52 shows these rates for grassland. The increase in pounds of beef produced per acre annually without harm to grass cover is a measure of the benefit of the remedial treatment.

Agricultural Income

In analyzing the land treatment and stabilizing costs and benefits the problem area in soil conservation was used as the evaluation unit. Counties lying wholly or almost entirely within a problem area in soil conservation were used as sampling units. Census data for crop distribution were totaled for the sampling units and from these data the percentage of cropland in each crop use was calculated for major crops grown in each problem area in soil conservation. The data derived from problem areas in soil conservation were then applied to creek or sections of river watersheds as shown in table 48.

Calculation of Changes in Agricultural Income: The following information was used to calculate changes in agricultural income for each problem area in soil conservation.

1. Production per unit for the various crop and pasture enterprises in each area.

2. Such expenses of production, including overhead as well as per unit production costs, as would be affected by the recommended program.

3. 1950 prices for commodities produced per unit, as tabulated below:

Unit Prices of Farm Products, 1950 1/

Item	Unit	Prices (dollars)
Corn	Bu.	1.240
Oats	Bu.	0.810
Grain Sorghum	Bu.	1.010
Peanuts	Lb.	0.103
Flax	Bu.	3.120
Cotton	Lb. 2/	0.386
Forage Sorghum	Ton	16.220
Alfalfa Hay, Baled	Ton	28.020
All Hay, Baled	Ton	16.220
Beef Cattle	Cwt.	24.970

1/ Division of Agricultural Statistics, BAE, USDA, Austin, Texas. Mid-month Average of Prices Received, State of Texas.

2/ Includes value of cotton seed.

Calculation of the Effects of the Recommended Program on Agricultural Production and Income

Without Recommended Program: Changes in crop and pasture yields expected in the future without land treatment and stabilizing measures were considered. In most cases crop yields are expected to decline in the future without land treatment, and this was reflected in the estimated quantities of commodities which would be produced.

The acreages in each use and the income to be expected without land treatment and stabilizing measures were adjusted in accordance with the improvements that will result from the continuation of the going program. Only the differences that would exist between the going program and the recommended program were considered in measuring benefits and costs of the recommended program.

With Recommended Program: In the future, with land treatment and stabilizing measures applied, the land use was modified to provide for needed conversion of cropland or idle land to pasture. When retirement of cropland acreage to pasture was recommended, all of the idle land within the cropland acreage was converted first. If the idle land acreage was less than the recommended cropland conversion acreage, a further deduction in cropland was made and apportioned to the different crops on the basis of the percentage that each crop acreage was of total crop acreage. Any changes in crop and pasture yields expected to result from the program were applied to the adjusted cropland and grassland acreages.

Changes in Income: The major steps in the process of calculating changes in income in the future, with and without the recommended program, were as follows:

1. Crop yields were applied to the acreage in the various crops to determine the total units produced.

2. Livestock production per acre was applied to grassland acreage to get total production.

3. 1950 prices were applied to all commodities for which changes in the quantities produced were expected.

4. Production cost factors were applied to each commodity for which a change in quantity produced was expected.

5. The changes in income and cost were summarized for each commodity to obtain the gross and net changes in income and cost.

Annual Installation and Maintenance Costs of the Recommended Program

Private installation costs occasioned by the recommended program were calculated for each problem area in soil conservation and were converted to an annual basis by multiplying by an interest rate of 4 percent. Maintenance costs of the treatment measures were calculated on an annual basis.

Determination of Conservation Benefits and Costs

Annual conservation benefits and costs were determined by summarizing the differences in gross income and costs, with and without the recommended program, for each problem area in soil conservation, table 53. In this calculation a loss in gross income or an increased cost was classed as a cost, whereas a gain in gross income or a decreased cost was considered a benefit. It was assumed in these calculations that 100 percent of the farm land would be included in the participating acreage.

The land included within pool areas of floodwater retarding structures is included in this evaluation since evaluation of these structures and actual determination of their numbers is the final step in the survey. The subtraction of the benefits and costs from watershed totals would have had no effect on the total benefit-cost ratios and only a very small effect on the total program costs.

Table 53. Average Annual Costs (Farm Owner and Operator) and Conservation Benefits from the Recommended Land Treatment and Stabilizing Measures by Creek Watersheds, 1950 Prices

San Antonio River Watershed, Texas

Creek or Section of River Watershed	Annual Benefits (dollars)	Installation Costs (dollars)	Maintenance Costs (dollars)	Installation and Maintenance (dollars)	Operating Costs (dollars)	Total All Costs (dollars)
Upper San Antonio	1,681,088	32,824	56,577	89,401	458,881	548,282
Lower San Antonio	1,296,280	25,130	43,607	68,737	352,796	421,533
Upper Medina	176,222	5,111	6,043	11,154	57,923	69,077
Lower Medina	985,225	19,607	33,171	52,778	271,151	323,929
Upper Cibolo	112,835	2,972	3,961	6,933	34,696	41,629
Lower Cibolo	1,149,075	30,060	41,347	71,407	310,654	382,061
Ecleto	453,331	11,071	15,686	26,757	123,253	150,010
TOTAL	5,854,056	126,775	190,392	327,167	1,609,354	1,936,521

APPENDIX VII

IRRIGATION

HISTORY OF IRRIGATION DEVELOPMENT

Early irrigation in the San Antonio River Watershed had its beginning with the founding of Spanish Missions, at the present site of the city of San Antonio, early in the 18th Century. Anglo-American settlement and further small scale irrigation development came after the Civil War. Early projects utilized surface flow from springs or spring-fed streams.

Large scale development of irrigation in the San Antonio River Watershed began with the establishment of the original Medina project by a Dr. Pearson, an English engineer and financier. The project began as a private enterprise which proposed to put under irrigation some 34,500 acres of land in southwestern Bexar, southeastern Medina and northwestern Atascosa counties. Construction of the Medina Lake dam was started in 1911 1/. The storage dam, diversion dam and entire distribution system was completed in 1914. During the latter part of the construction phase, funds became insufficient to complete the project and the project was placed in receivership and remained in that state until 1925. The Medina-Bexar-Atascosa Counties Water Improvement District Number 1 was then organized to operate the project.

Shortly after the Water Improvement District was organized, boundaries were changed slightly from the original project and most of the land under the district in Medina County was cleared and developed for irrigation. In 1928, lands in Bexar County were cleared and developed for irrigation. The approximate area of land under Water Improvement District ditch in the San Antonio River Watershed at present is about 13,200 acres.

Irrigation from wells started in the late 1890's 2/ following the discovery of ground water under artesian pressure. Some 250 acres of land near San Antonio were irrigated from artesian wells in 1897. Scattered development followed and by 1904 several artesian wells were furnishing water for irrigation in this area.

Pump irrigation from wells developed along with the search for ground water under artesian pressure. Many of the irrigation wells now being pumped have a small head of artesian flow but not enough to be used for irrigation without pumping.

In 1949 approximately 10,370 3/ acres of land in the San Antonio River Watershed were irrigated. Of this amount about 9,260 acres were irrigated

1/ Preliminary Report of Bexar-Medina-Atascosa Counties Water Improvement District Number 1, by Clint W. Bracher, SCS.
2/ Irrigated agriculture in Texas by W. F. Hughes and Joe R. Motheral.
3/ Preliminary, 1950 Census of Agriculture.

by gravity flow from stream diversion and pumped wells, the greater quantity of water coming from pumped wells. The sprinkler method of irrigation was used on about 1,110 acres.

Irrigation farming now centers around two main types, production of commercial truck crops and diversified farming.

WATER RIGHTS AND APPROPRIATIONS

The status of water rights and appropriations in the San Antonio River Watershed was obtained from the State Board of Water Engineers. This information is listed as follows:

1. Between May 15 and September 15 of each year, all normal stream flow of the San Antonio River and tributaries is appropriated under recognized permits.

2. During the periods of record 1924-1928 and 1939-1948 an annual excess above recognized appropriations of some 425,000 acre-feet passed the Goliad stream-flow station.

3. In 1939 this excess was quite low, 132,000 acre-feet, and in two other years the excesses were between 200,000 and 300,000 acre-feet. Several years, of course, showed tremendous excesses, and the average minimum of all years is in excess of 300,000 acre-feet.

4. Generally speaking, there is no objection to the impoundment of flood flows up to this average annual excess providing substantial spill occurs from all proposed dams, or that the design of the dams be such as to pass water temporarily impounded but needed downstream from these dams to meet recognized appropriations.

INVESTIGATION OF SUPPLEMENTARY IRRIGATION

During the investigation of floodwater retarding structures, Appendices III and V, each site was investigated to determine the feasibility of providing additional storage for use in irrigation of adjacent croplands. Additional embankment and a distribution system added to the retarding structure would make full use of the site and would contribute to the conservation of water supplies within the San Antonio River Watershed. The addition of storage capacity for irrigation uses on recommended floodwater retarding structures is feasible in many cases.

The following pages discuss briefly the procedures and factors used in the investigation of the feasibility of providing additional storage for irrigation purposes.

Land Available for Irrigation

Hydrologic studies of the San Antonio River Watershed show that the development of adequate surface water supplies for irrigation in connection with floodwater retarding structures is practical in areas similar to the Calaveras and Escondido Creek Watersheds. The discussion of soils for irrigation is confined to these two watersheds.

The Calaveras Creek alluvial soils are usually deep, with moderately light textured surface soils over permeable fine sandy loam or sandy clay subsoils. Soil profiles, as a whole, allow easy penetration of roots, air and water and free drainage, yet have good available water storage capacity, table 54. These soils are usually productive, comparatively smooth, present no particular problems in water application or coverage and may be irrigated by furrow, border or sprinkler methods. Field investigations show that alluvial soils occur in small tracts. For example, alluvial soils occupy only 21 percent of the area for which water might be made available for irrigation from floodwater retarding structure number 9.

Upland soils are deep with loose sandy surface soils over heavy plastic clay subsoils. The surface 12 to 18 inches of the typical upland soil profile is freely permeable, allows easy penetration of roots, air and water and has a moderate available water storage capacity, table 54. The subsoil portion of this profile, since it is a heavy clay, is almost impervious to water and not conducive to root and air penetration. This condition can be greatly improved by including deep rooted legumes in crop rotations. Due to the open porous condition of upland surface soils, quick coverage and even distribution of irrigation waters will be difficult by any method other than sprinkler irrigation.

Escondido Creek alluvial soils are deep with fine to medium textured surface soils over slowly permeable subsoils. Profiles as a whole take water rather slowly but are capable of absorbing and storing large quantities of water in an available form for crop use. Under-drainage is somewhat restricted but judicious use of irrigation water and the inclusion of deep rooted crops in rotations will improve this condition. These soils are usually productive, respond readily to good soil management practices and lie in such a position that they can be readily supplied with irrigation water.

Upland soils are deep, fine textured, slowly permeable and well drained with a high available water storage capacity. They are usually somewhat less productive than adjacent alluvial soils but will respond readily to good soil management practices. Most of the upland soils adjacent to floodwater retarding structure sites, where water could be stored for irrigation, are somewhat sloping and will require extensive land leveling if gravity irrigated. For this reason it is believed that sprinkler type irrigation, which requires a minimum of land leveling, will be the most practical and economical for upland soils of the Escondido Creek Watershed.

Table 54. Estimated Available Water Holding Capacities of Alluvial and Upland Soils by Sample Watersheds

San Antonio River Watershed, Texas

Drainage	Soil Position	Inches of Available Water Stored to Depths of:			
		1'	2'	3'	4'
Calaveras Creek	Bottoms or Terraces	1.5	3	4.5	6
Calaveras Creek	Uplands	1	2	Impervious has little storage capacity below 2 feet.	
Escondido Creek	Bottoms or Terraces	2	4-5	6-8	8-11
Escondido Creek	Uplands	2	4-5	6-8	8-11

Soil investigations indicate that lands suitable for irrigation are available in sufficient acreages within reasonable distance from the sites to utilize the calculated quantity of water which can be stored for irrigation in the Calaveras and Escondido Creek Watersheds.

Crops Grown Under Irrigation

In determining present types of crops grown under irrigation, in the San Antonio River Watershed, Bexar County was used as a sample. Percentage composition by types of crops commonly grown under irrigation is shown in the following tabulation:

General Farms

Crops	Percent of Total Acreage in Irrigated Farms
Cotton	3.42
Corn	5.48
Grain Sorghums	3.42
Forage Sorghums	6.85
Peanuts	.69
Oats (for grain)	6.85
Oats (for pasture)	34.25
Flax	2.05
Clover	2.74
Tame Pasture (Johnson and Sudan Grass)	27.40
Pasture (native grasses)	6.85

Truck Farms

Crops 1/	Percent of Total Acreage in Irrigated Farms 2/
Beans (green)	6.82
Beets	3.47
Cabbage	10.19
Cantaloupes	2.69
Carrots	11.42
Cucumbers	2.95
Lettuce	1.39
Onions (dry)	2.90
Peas (English)	.78
Spinach	6.25
Tomatoes	6.30
Watermelons	12.03
Other Vegetables	32.81

1/ From 1949 crop year data - as shown in 1950 Preliminary Census for Bexar County.

2/ This percentage does not account for land on which two or three successive crops are grown during one year.

Crop Yields Under Irrigation

It is believed that most presently irrigated lands in the watershed are adequately supplied with irrigation water, except the areas which receive water from Medina Lake. Water supply to these lands has been very erratic due to seepage losses from the lake and the distribution system. It is thought that crop yields on lands supplied from Medina Lake would be very similar to yields of other irrigated areas of this watershed if an adequate and dependable supply of irrigation water were available. Estimated yields of various crops commonly grown under irrigation in the San Antonio River Watershed are shown in table 55.

Methods of Irrigation Water Application

Conservation irrigation has been defined as follows: "Conservation irrigation consists of the application and maintenance of practices which will maintain and improve soil productivity, hold erosion to the minimum, promote efficient use of rainfall and irrigation water, prevent excessive leaching of plant foods, dispose of excess water in an orderly manner that will prevent erosion and prevent damage to the land by water logging or accumulation of harmful salts."

Two methods of irrigation which will accomplish the above objectives and which appear to be well adapted to the area are level irrigation and sprinkler irrigation.

The sprinkler method of irrigation is probably the most suitable for use in supplemental irrigation from surface water supplies. Selection of the method will depend upon the wishes of the irrigator and a detailed survey of the irrigable land to determine which system would be the most practical and economically feasible.

Surface Water Resources

An examination of figure 11, Appendix III, shows that the average annual precipitation on the San Antonio River Watershed ranges from approximately 27 to 35 inches. Data contained in Appendix III indicates that the average annual runoff varies widely between areas, due primarily to flow from springs in the vicinity of San Antonio. Balancing spring flows, diversions and storage shows that surface runoff at the principal gaging stations does not vary materially, as indicated in the following tabulation 1/:

1/ Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas, Corps of Engineers, Department of the Army.

Table 55. Estimated Average Yield of Various Crops Grown Under Irrigation

San Antonio River Watershed, Texas 1/

Crop	Unit	Yield per Acre
Vegetables		
Carrots	50 # Bags	800
Cabbage	Tons	10
Corn (Sweet)	Bushels	85-100
Cauliflower	Dozen Heads	350
Collard (Greens)	Dozen Bunches (Leaf)	1,000
Beans (Green)	Bushels	220
Beets	Bushels	450
Broccoli	Pounds	4,000
Potatoes (Irish #1)	Bushels	175
Potatoes (Sweet)	Bushels	300-350
Parsnip	Bushels	400
Parsley	Dozen Bunches	3,000
Lettuce (Head)	Bushels	500
Radishes	Bushels	150
Spinach	Bushels	800
Squash (large Commercial)	Bushels	450
Turnips	Bushels	300
Field Crops		
Cotton	Pounds Lint Cotton	500
Corn	Bushels	50
Grain Sorghum	Bushels	55
Forage Sorghum	Tons	8
Peanuts	Bushels	40
Oats	Bushels	50
Flax	Bushels	15
Wild Hay	Tons	2
Pasture	A.U.M.	24
Clover	Pounds Seed	600

1/ Sources of Data: (1) Henry Van De Walle, Irrigation Farmer, Bexar County. (2) Mr. Tate, County Agent, Bexar County. (3) Irrigated Agriculture in Texas, Hughes and Motheral. (4) Clint Bracher, SCS, Uvalde, Texas.

Stream	Gaging Station	Total Runoff	Spring Flow	Surface Runoff	
		(ac.-ft.)	(ac.-ft.)	(ac.-ft.)	(inches)
San Antonio River	San Antonio	53,792	48,100	5,692	2.60
	Falls City	238,519	53,200	185,319	2.31 1/
	Goliad	419,764	53,200	366,564	2.11 1/

1/ Exclusive of the 633 square miles of drainage area above Medina Reservoir.

The decrease in surface runoff from San Antonio to Goliad is caused by effect of drainage area size and is not the result of lesser amounts of surface runoff in the Rio Grande Plain, since surface runoff normally increases with an increase in annual precipitation.

The estimated ranges in surface runoff at their source, as affected by annual precipitation, for the various problem areas in soil conservation appears in the following tabulation:

Area	Annual Runoff, Inches		
	Maximum	Minimum	Mean
Edwards Plateau	5.00-6.00	0.30-0.40	1.50-2.00
Rio Grande Plain	6.00-8.00	0.40-0.60	2.00-3.00
Blackland Prairie	8.00-10.00	0.50-0.70	2.50-3.00
Forested Coastal Plain	7.00-8.00	0.40-0.50	2.50-3.00

The Medina Reservoir is the principal storage reservoir in the watershed. Nearly all of the runoff above the dam site is stored in this irrigation pool and the 633 square mile drainage area is not considered as contributing to downstream water supplies.

Evaporation losses from reservoir water surfaces, irrigation, and municipal uses have some effect on the amount of runoff, but these effects are small in relation to the runoff from the entire watershed.

The monthly distribution of runoff as shown in table 56 indicates that greater amounts of runoff occur in the spring and fall months, approximately 85 percent occurring during the growing season from March through November.

Table 56. Distribution of Monthly and Annual Runoff 1/ at Selected Stations

San Antonio River Watershed, Texas

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Cibolo Creek near Falls City, drainage area 837 square miles, Nov. 1930-Sept. 30, 1949.													
Maximum-Ac.-Ft.	10235	6407	7359	19756	14321	35901	41455	36695	34315	9560	10651	10513	
Inches	.23	.14	.16	.44	.32	.80	.93	.82	.77	.21	.24	.24	
Year	1938	1945	1938	1941	1935	1935	1942	1946	1942	1942	1940	1940	
Average-Ac.-Ft.	4689	3863	4190	11956	14564	12053	11230	4885	9838	4841	3765	4845	
Inches	.11	.09	.09	.27	.33	.27	.25	.11	.22	.11	.08	.11	2.04
Minimum-Ac.-Ft.	8	24	22	20	14	16	14	8	14	10	14	12	
Year	1933	1940	1933, 1940	1933	1933	1933, 1934, 1939	1932, 1934, 1939, 1948	1948	1940	1940	1931	1932	
San Antonio River near Falls City, drainage area 2,106 square miles, Apr. 1925-Sept. 30, 1949													
Maximum-Ac.-Ft.	7180	7180	4165	15769	16820	27372	30546	20033	83704	13547	12218	6347	
Inches	.06	.06	.04	.14	.15	.24	.27	.18	.75	.12	.11	.06	
Year	1945	1941	1938	1926	1929	1935	1936	1946	1946	1936	1940	1940	
Average-Ac.-Ft.	15837	14437	15110	21726	27387	29159	21979	12366	27470	19804	14245	14985	
Inches	.14	.13	.13	.19	.24	.26	.20	.11	.24	.18	.13	.13	2.08
Minimum-Ac.-Ft.	93	141	119	107	71	113	85	75	85	113	127	113	
Year	1931	1931	1929	1929	1928	1928	1928	1928	1930	1927	1927	1930	
San Antonio River at Goliad, drainage area 3,896 square miles June 1924-Sept. 1928 Feb. 1939-Sept. 30, 1939													
Maximum-Ac.-Ft.	10195	9501	20232	28562	29753	18843	63472	24397	56728	55141	21422	16205	
Inches	.05	.05	.10	.14	.14	.09	.31	.12	.27	.27	.10	.08	
Year	1929	1941	1929	1941	1941	1949	1942	1946	1942	1946	1940	1940	
Average-Ac.-Ft.	20543	21499	25291	42979	51192	34132	40012	19687	49753	47639	29723	23160	
Inches	.10	.10	.12	.21	.25	.16	.19	.09	.24	.23	.14	.11	1.94
Minimum-Ac.-Ft.	161	206	218	202	155	167	103	87	95	109	179	200	
Year	1928	1929	1926	1927	1928	1929	1928	1927	1927, 1928	1927	1939	1939	

1/ Based on U. S. Geological Survey Water Supply Papers. As of Sept. 30, 1949.

An examination was made of the ground water or base flow for selected areas as shown in table 57. Surface runoff was separated from the ground-water flow for the period of gaged records. The data contained in table 57 indicates that ground-water flow in Cibolo Creek is approximately 19 percent of the total annual runoff, and ranges from approximately 12 percent in April to 39 percent in January. These percentages are considerably lower in the 6-month period April-September than for the remaining months of the year. Ground-water flow is much higher, as percent of total runoff at the gaging stations on the San Antonio River, and is due primarily to spring flow in the vicinity of San Antonio. This spring flow amounts to approximately 86 percent of the total runoff on San Pedro Creek and decreases to 56 percent at the Falls City gage and 46 percent at the Goliad gage. This decrease is due to the concentration of the spring flow in the headwaters of the San Antonio River, with essentially no further contribution below the junction of the Medina River and the San Antonio River.

It was considered that drought conditions prevail when annual precipitation is less than 85 percent of normal. By this criterion it was determined that 50 percent of the years, or 33 out of 66, were droughty at San Antonio. Crop yields may be approximately normal if normal or above normal precipitation occurs during the growing season, even though annual precipitation amounts may indicate droughty conditions. The amounts of precipitation in the months preceding any given year, and prolonged periods having below normal precipitation which lead to critical shortage of water resources, also influence crop yields. Therefore, annual precipitation is not a true indicator of drought unless several climatic factors are evaluated.

The year 1917 was the most critical single year at San Antonio (66-year period of record) as precipitation was only 37.2 percent of normal. The period 1909-1911 was the most critical 3-year period, with 61.1 percent of normal precipitation. Table 16, Appendix III, contains additional data concerning distribution of precipitation for certain periods and at various locations.

The occurrence of the most critical 3-year drought periods during 66 years of record at San Antonio are shown in the following tabulation:

Period	Normal Precipitation (inches)	Below Normal Precipitation (inches)	Percent Below Normal
1909-1911	81.54	31.72	38.9
1897-1899	81.54	23.48	28.8
1892-1894	81.54	15.74	19.3
1924-1926	81.54	13.13	16.1
1937-1939	81.54	13.38	16.4

The above data indicate that five 3-year periods were at least 16 percent deficient in precipitation.

Table 57. Average Monthly and Annual Groundwater Flow as Related to Total Runoff at Selected Stations 1/

San Antonio River Watershed, Texas

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Cibolo Creek near Falls City, drainage area 837 square miles, Nov. 1930-Sept. 30, 1949													
Total Runoff, Acre-Feet	4689	3863	4190	11956	14564	12053	11230	4885	9838	4841	3765	4845	90719
Groundwater Flow, Acre-Feet	1847	1352	1479	1399	1922	1663	1539	1001	1190	1409	1242	1352	17395
Groundwater as percent of total	39.4	35.0	35.3	11.7	13.2	13.8	13.7	20.5	12.1	29.1	33.0	27.9	19.2
San Antonio River near Falls City, drainage area 2,106 2/ square miles, Apr. 1925-Sept. 30, 1949													
Total Runoff, Acre-Feet	15837	14437	15110	21726	27387	29159	21979	12366	27470	19804	14245	14985	234505
Groundwater Flow, Acre-Feet	12068	11290	11756	10798	10298	11343	11143	8533	10164	11704	10954	11598	131649
Groundwater as percent of total	76.2	78.2	77.8	49.7	37.6	38.9	50.7	69.0	37.0	59.1	76.9	77.4	56.1
San Antonio River at Goliad, drainage area 3,896 2/ square miles, June 1924-Sept. 1928; Feb. 1939-Sept. 30, 1949													
Total Runoff, Acre-Feet	20543	21499	25291	42979	51192	34132	40012	19687	49753	47639	29723	23160	405610
Groundwater Flow, Acre-Feet	15366	15329	18260	14398	18122	15871	13844	11123	13981	16293	16883	16143	185613
Groundwater as percent of Total	74.8	71.3	72.2	33.5	35.4	46.5	34.6	56.5	28.1	34.2	56.8	69.7	45.8

1/ San Antonio River data materially affected by spring flow, diversions and irrigation.
2/ Includes 633 square miles above Medina Lake dam site. Source of Data: U. S. Geological Survey Water-Supply Papers.

Effects of the Recommended Program on Water Resources

Consideration was given to the probable effects of the recommended program on the average annual runoff. A part of the additional water infiltrated into the surface of the watershed due to the application of complete land treatment would be disposed of by subsurface movement to streams. Another part would be percolated to deep ground-water aquifers.

It is expected that in some areas deep ground-water reservoirs will be replenished within a few years after the land treatment measures become effective and that, at that time, the amounts of water moving into the ground-water reservoirs will be substantially reduced.

The land treatment measures will improve the physical condition and increase the waterholding capacity of the soil, which will make additional infiltrated water available to plants. It is expected that increased vegetative cover will result in higher transpiration uses of infiltrated water. However, this increase in cover will provide more shade, litter and protection from winds, thereby reducing the losses due to land surface evaporation. These effects may change the present evaporation-transpiration relationship but it is the opinion of leading hydrologists that the increase in transpiration will be offset largely by a decrease in evaporation. The net change in average annual water yield, therefore, would be small.

Table 58 shows a summary of the effect of the application of land treatment measures and recommended floodwater retarding structures on runoff at three gaging stations. The relative amounts are expressed as percentages of present runoff. The average annual reduction in runoff due to the land treatment program was obtained by expansion of the reductions computed in sample watersheds to the areas each sample watershed represented. Increased transpiration and evaporation will account for part of the additional water infiltrated annually into the soil. The remainder was considered as percolating into the deep ground-water aquifers or as ground-water return flow. The part of the amount infiltrated annually considered as ground-water return flow was determined from estimated rates of return flow for each geologic formation in the area. The amount of water percolated into deep aquifers was obtained by subtracting the computed amount of return flow from the additional amount annually infiltrated due to application of complete land treatment program.

The evaporation from water surfaces of recommended floodwater retarding structures was based on the mean surface area in the permanent pools. Net evaporation losses from water surfaces as shown in table 58 were used in computing the water losses from the recommended floodwater retarding structures.

Table 58. Effect of the Total Land Treatment Program and Recommended Floodwater Retarding Structures on Average Annual Runoff at Selected Stations 1/

San Antonio River Watershed, Texas

Condition	Acre-Feet	Percent of Present Annual Runoff (percent)
Cibolo Creek at Falls City Gage, 837 square miles		
Average Annual Runoff	90,719	
Increased Infiltration Due to Land Treatment	17,249	19.01
Increased Return to Stream Flow	8,996	9.91
Increased Deep Percolation	8,253	9.10
San Antonio River at Falls City Gage, 2,106 square miles		
Average Annual Runoff	234,505	
Increased Infiltration Due to Land Treatment	52,363	22.33
Increased Return to Stream Flow	26,812	11.43
Increased Deep Percolation	25,551	10.90
Evaporation from Permanent Pools	2,006	0.85
Total Reduction in Stream Flow	27,557	11.75
San Antonio River at Goliad Gage, 3,896 square miles		
Average Annual Runoff	405,610	
Increased Infiltration Due to Land Treatment	96,870	23.88
Increased Return to Stream Flow	48,657	12.00
Increased Deep Percolation	48,214	11.89
Evaporation from Permanent Pools	5,599	1.38
Total Reduction in Stream Flow	53,813	13.27

1/ These figures represent the maximum changes expected as a result of the watershed program.

Surface Water Available for Irrigation Use

In investigating additional storage for irrigation use in recommended floodwater retarding structures the available precipitation was considered as being supplementary to the storage in the structures. Floodwater retarding structures in which at least 3 inches of irrigation storage capacity could be provided in addition to detention storage were investigated.

Mass curves of runoff were developed for several gaged areas in order to determine the expected volume of runoff for certain periods and the expected frequency of occurrence of critical drought periods. An inflow-loss and use balance sheet was used to compute the monthly changes in irrigation storage in a reservoir, table 59. The period January 1924-1935 was selected since this period includes the critical period 1924-1926 and also shows drought conditions in 1930 and 1933. Due to low inflow and heavy evaporation losses and crop use, the irrigation pool was not restored until June 1935. It was assumed that the irrigation pool was full at the beginning of the period investigated.

These changes in stored volumes were related to stage-area and stage-runoff curves. The following computations were made for each month:

1. Precipitation in acre-feet on the surface area of the reservoir.

2. Runoff in acre-feet from the total area above the reservoir; considered as inflow.

3. Evaporation in acre-feet from the mean surface area of the reservoir; based on pan evaporation studies at San Antonio, table 60.

4. Precipitation in acre-feet on the area under irrigation; subtracted from the net monthly requirement of crops.

5. A 60 percent irrigation efficiency, or a 15 percent loss in transmission and 25 percent loss on the area being irrigated; estimated by irrigation specialist.

6. Net monthly irrigation requirements for alfalfa were determined by the irrigation specialist; alfalfa requirements were used as it has the highest requirement of any crop commonly irrigated.

Table 59 shows the monthly changes in irrigation storage as affected by the various factors listed above.

Several trial computations were made using various amounts of irrigation storage and an assumed area to be irrigated, so that sufficient storage would be provided for season-long irrigation throughout the critical period selected.

Table 59. Monthly Changes in Irrigation Storage as Affected by Inflow, Evaporation, and Irrigation, 58 Acres of Alfalfa - Calaveras Creek, Floodwater Retarding Site No. 2. 1/

San Antonio River Watershed, Texas

Year and Month	Storage in Reservoir: Storage	Storage in Reservoir: Surface Level	Storage in Reservoir: Surface Area	Precipitation in Reservoir	Runoff Above Reservoir	Reservoir Evaporation: From Surface	Reservoir Evaporation: Total	Water Requirement: Per Acre Irrigated	Water Requirement: Total	Volume of Precipitation on Irrigated Area	Net Water Use: 100% Efficiency	Net Water Use: 60% Efficiency	Storage in Reservoir at End of Month
	(ac.ft.)	(elev.)	(acres)	(ac.ft.)	(ac.ft.)	(inch)	(ac.ft.)	(inches)	(ac.ft.)	(ac.ft.)	(ac.ft.)	(ac.ft)	(ac.ft.)
1925													
Jan.	672	472.9	104	2	0	2.32	20	2.2	11	1	10	17	637
Feb.	637	472.6	101	1	0	2.85	24	2.7	13	0	13	22	592
Mar.	592	472.2	96	5	0	4.19	35	3.4	16	3	13	22	540
Apr.	540	471.7	91	3	0	5.20	41	4.1	20	2	18	30	472
May	472	471.0	83	17	87	6.12	45	4.7	23	13	10	17	514
June	514	471.3	88	3	0	7.47	55	6.8	33	2	31	52	410
July	410	470.2	76	8	0	8.55	58	6.5	31	6	25	42	318
Aug.	318	469.0	65	12	0	8.64	53	6.2	30	10	20	33	244
Sept.	244	467.1	53	16	16	6.40	34	5.4	26	18	8	13	229
Oct.	229	467.0	51	9	25	4.79	23	4.1	20	10	10	17	223
Nov.	223	466.8	50	4	0	2.97	13	3.0	14	5	9	15	199
Dec.	199	466.3	46	4	0	2.30	9	2.1	10	6	4	7	187
Totals	-	-	-	84	128	61.80	410	-	247	76	171	287	-

1/ Drainage Area 5.83 square miles.

Table 60. Monthly Evaporation Data

San Antonio River Watershed, Texas

Month	Beeville, Texas 1/		San Antonio, Texas 2/	
	Observed Pan Evaporation (inches)	Gross Exaporation from Reservoir Surface (inches)	Observed Pan Evaporation (inches)	Gross Evaporation from Reservoir Surface (inches)
January	2.31	2.17	2.46	2.32
February	2.83	2.66	3.03	2.85
March	4.44	4.18	4.46	4.19
April	5.22	4.91	5.53	5.20
May	6.23	5.85	6.51	6.12
June	7.01	6.59	7.95	7.47
July	7.44	6.99	9.09	8.55
August	7.20	6.77	9.19	8.64
September	5.57	5.24	6.81	6.40
October	4.59	4.31	5.10	4.79
November	3.18	2.99	3.16	2.97
December	2.44	2.30	2.45	2.30
Annual	58.46	54.96	65.74	61.80

1/ Pan coefficient = 0.94; 1915-1947.

2/ Pan coefficient = 0.94; 1907-1930.

An examination of the data compiled in the study revealed that net evaporation from water surfaces may account for approximately 41 percent of the total inflow into a reservoir where total inflow was considered as precipitation on the pool surface plus runoff from the watershed.

The computations of irrigation storage changes for one year are shown in table 59. The year 1925 was selected, since it was the most critical in the period January 1924-June 1935. There was a net loss in storage of 28 percent for the year preceding 1925. Precipitation on the area irrigated in 1925 amounted to only 31 percent of the gross water requirement for alfalfa. Inflow into the reservoir accounted for approximately 52 percent of the gross requirements, which was in turn further reduced by evaporation. The irrigation storage was reduced to zero at the end of December, although crop needs were met. Inflow early in 1926 restored some of the irrigation storage, with essentially no shortage of water thereafter.

Restoration of depleted storage for irrigation was a slow process since the period selected also included critical periods other than 1924-1926. The irrigation storage pool was up to full capacity in June 1935.

Evaluations were made for both 3.00 and 4.00 inches of irrigation storage and the irrigation of 58, 87 and 117 acres from a reservoir (Site Number 2, Calaveras Creek) having 5.83 square miles of contributing drainage area. This is 10, 15, and 20 acres of irrigated land for each square mile of drainage area.

It was determined from evaluations that 3.00 inches of storage at this site would supply water for 58 acres throughout the critical period with essentially no crop losses. If 15 acres per square mile, or 87 acres, were irrigated a water deficit of approximately 11 percent could be expected. This deficit would amount to an average of approximately 50 percent monthly for 33 months out of a total of 138 months in the period of study. The shortages usually occur during the months October-February and only slight effect on expected yields would result.

If 20 acres per square mile, or 117 acres, were irrigated from the 933 acre-feet of storage there would be an estimated deficit 20 percent of the time. On an annual basis this would result in no irrigation one year in five, although expected yields would probably be reduced less than 20 percent due to the fact that shortages for most crops usually occur during the dormant period.

Costs of Irrigation Storage

An investigation of floodwater retarding structure number 9 in Calaveras Creek was made to determine the cost of the storage and water distribution features of a gravity irrigation system. Embankment costs estimated included only the additional costs attributable to the storage of irrigation water. A 48-acre area, or 10 acres for each square mile of drainage area, as determined by earlier studies was used in this trial.

Figures 44, 45, and 46 show pool plan, dam elevation, and typical dam section as affected by the irrigation storage. The data from soils and topographic surveys are shown on figures 47 and 48. One feature not shown on the topographic map is a number of old field terraces, all slightly benched, which must be considered in estimating the leveling costs. Table 61 shows the costs which would be applicable to irrigation using the criteria listed above. Comparable costs were obtained from evaluations of other sites with the following exceptions:

1. Earth-fill costs varied widely between various dam sites.

2. Costs for clearing varied widely. In several cases it was necessary to include wooded land in the irrigated area because of insufficient open land located where it could be served by a gravity system. It was possible in all cases to find open upland suitable for sprinkler irrigation.

Previous experience has shown that a sprinkler system for irrigation, exclusive of the water supply, can be set up for approximately $100 per acre irrigated. This is essentially the same as the cost for a gravity system with the above exceptions and for areas up to 50-75 acres in size either might be used. On larger systems, generally more than 150 acres in size, there is a possibility of serving parts of the area with gravity and the remainder with the sprinkler system. It was found to be more economical in several cases to use sprinkler systems and thus greatly reduce leveling costs, avoid expensive clearing, and utilize land lying near the water supply.

An analysis of each recommended retarding structure site, where sufficient storage for irrigation could be provided, was made to determine the suitability of soils for irrigation, the type of irrigation system best adapted for each site, and other pertinent data, as shown in table 62. No wooded areas are included because of the high clearing costs, and generally excessive leveling costs.

Method of Determining Irrigation Benefits

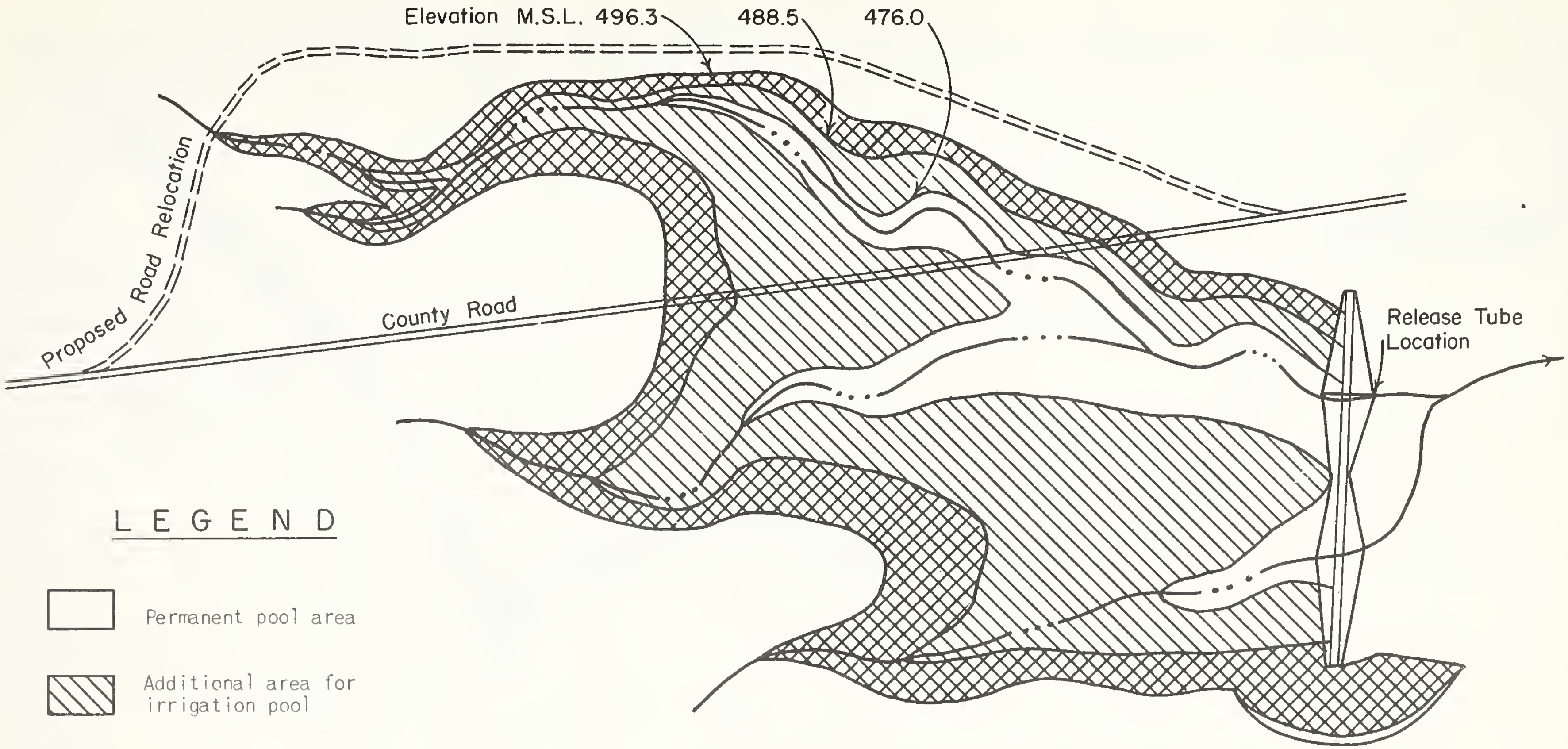
The method used in determining expected benefits from irrigation is similar to that used in determining expected benefits from intensified use of flood plain lands, Appendix VI. The area which would be irrigated by the proposed irrigation systems is in crops at present.

The average annual gross value of production in the area proposed for irrigation was determined both for present dryland conditions and under irrigated conditions. Costs of production, including machinery expense, fertilizer, labor, water application and an added charge for taxes and overhead, was deducted from the gross return to give the net increase in value of annual production. Yields under irrigation are shown in table 55.

UNITED STATES
DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF

WESTERN GULF REGION
LOUIS P. MERRILL - REGIONAL DIRECTOR



LEGEND

Permanent pool area

Additional area for irrigation pool

Additional area for detention storage

Figure 44
AREAS INUNDATED BY VARIOUS POOLS
FLOODWATER RETARDING STRUCTURE NO.9
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

W.C.B. 3-28-52 4-N-8222-18

UNITED STATES
DEPARTMENT OF AGRICULTURE

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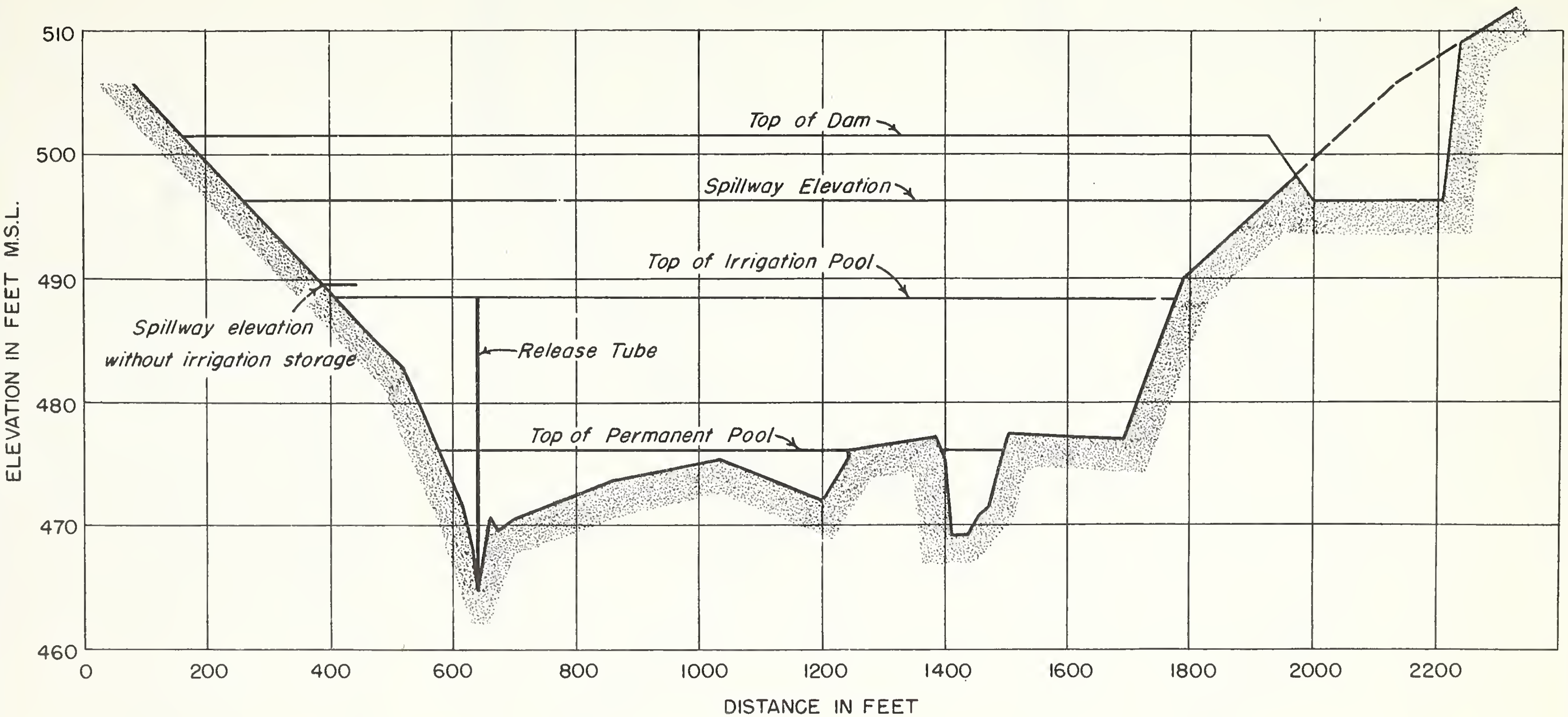

Figure 45

VALLEY SECTION AT FLOODWATER RETARDING
STRUCTURE NO.9 CALAVERAS CREEK
SHOWING VARIOUS POOL LEVELS

SAN ANTONIO RIVER WATERSHED

TEXAS

W.C.B. 4-1-52 4-N-8222-20

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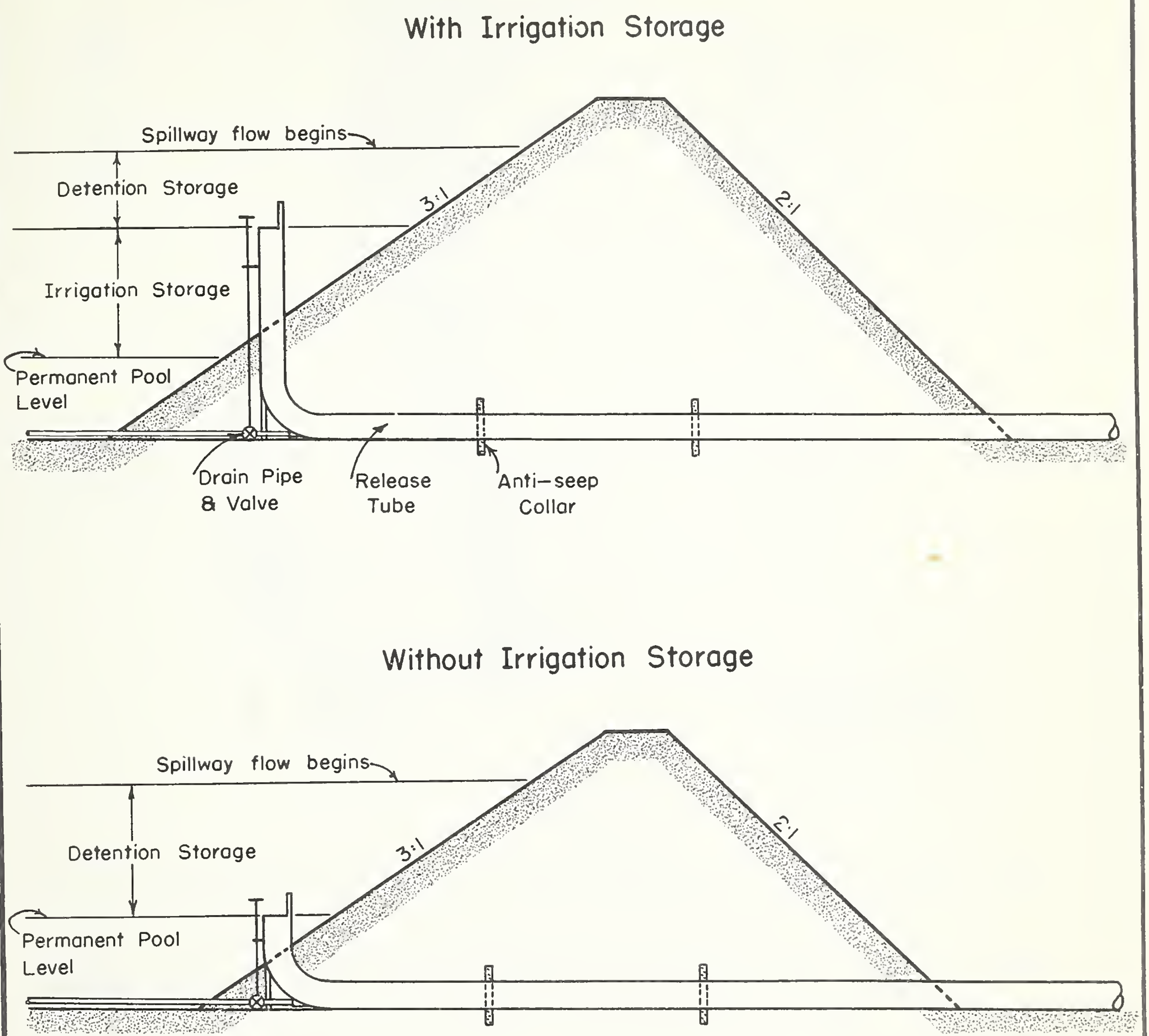
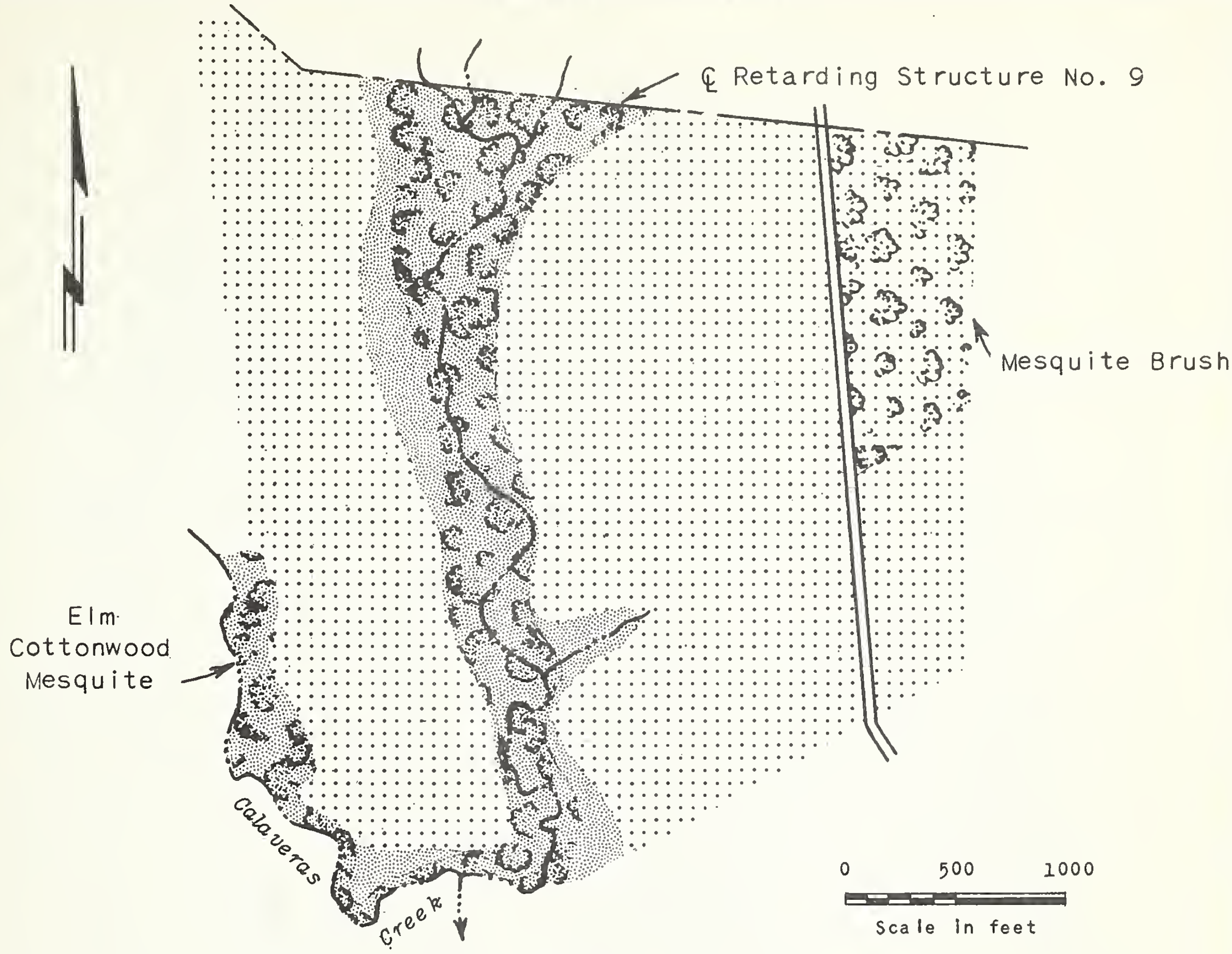


Figure 46

SECTIONS OF FLOODWATER RETARDING STRUCTURE NO.9
CALAVERAS CREEK
THROUGH THE RELEASE TUBE
SHOWING POOL ELEVATIONS AND EMBANKMENT
WITH & WITHOUT IRRIGATION STORAGE
SAN ANTONIO RIVER WATERSHED
TEXAS

W.C.B. 3-27-52 4-N-8222-14



LEGEND

Deep medium textured slowly permeable upland soils with loose sandy surface soils over heavy plastic clay subsoils.

Deep medium textured permeable alluvial soils with dark sandy loam surface soils over permeable sandy clay subsoils.

Wooded areas.

Figure 47
SOIL GROUPS
AREA BELOW FLOODWATER RETARDING STRUCTURE NO. 9
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL

REFERENCE

CARTOGRAPHIC APPROVAL TECHNICAL APPROVAL

COMPILED TRACED R.D.B CHECKED DATE 4-24-5

4-L-8222-40

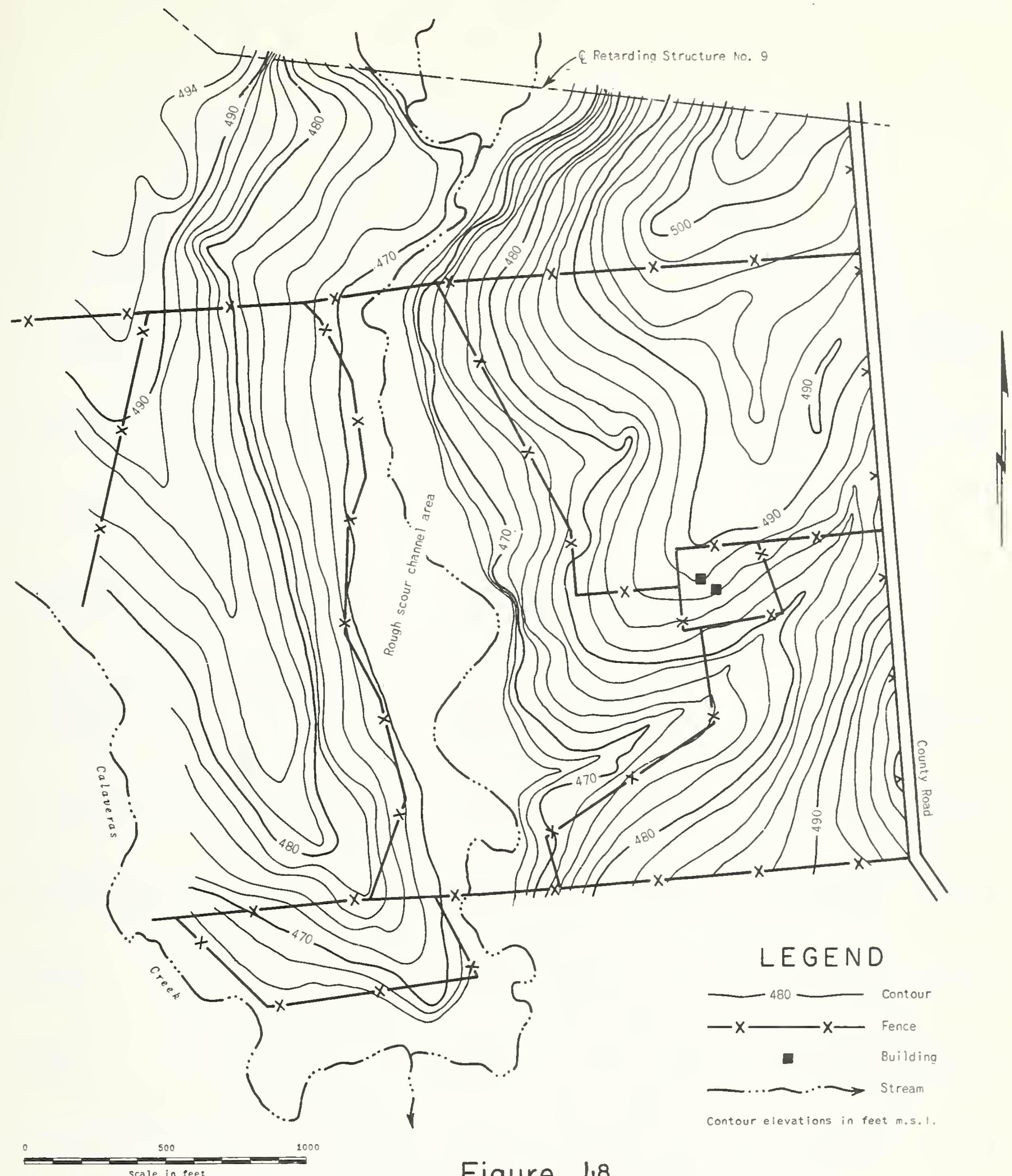


Figure 48
TOPOGRAPHIC MAP
AREA BELOW FLOODWATER RETARDING STRUCTURE NO. 9
CALAVERAS CREEK
SAN ANTONIO RIVER WATERSHED
TEXAS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ROBERT M. SALTER - CHIEF
REGION 4 DIRECTOR - LOUIS P. MERRILL
REFERENCE

CARTOGRAPHIC APPROVAL TECHNICAL APPROVAL
Bilyeu Sam Maner
COMPILED TRACED CHECKED DATE
G.G.C. R.D.B 4-25-52

4-R-8222-43

Table 61. Irrigation Costs, Retarding Structure Site No. 9, Calaveras Creek

San Antonio River Watershed, Texas

Item	Unit	Number	Total Cost on System (dollars)	Cost Per Acre of System (dollars)
Additional Earth Fill 1/	Cu. Yd.	42,620	29,271.00	609.81
Leveling	Acres	48	1,440.00	30.00
Construction of Borders	Lin. Ft.	48,000	144.00	3.00
Construction of Supply Canal	Lin. Ft.	3,000	1,140.00	23.75
Construction of Laterals	Lin. Ft.	15,840	450.00	9.38
Outlet Pipe	Lin. Ft.	200	1,040.00	21.67
Valve	No.	1	200.00	4.17
Meter	No.	1	200.00	4.17
Stilling Basin	No.	1	80.00	1.67
Main Canal Checks	No.	3	60.00	1.25
Lateral Checks	No.	20	180.00	3.75
Total	-	-	34,205.00	712.60

1/ Includes additional core, stripping, and spillway costs.

Table 62. Irrigation Costs, Floodwater Retarding Structure Sites, Calaveras and Escondido Creeks

San Antonio River Watershed, Texas

Creek Watershed	Site No.	Acres Suitable for Sprinkler Irrigation	Acres Suitable for Gravity Irrigation	Distribution System Costs at $100 per Acre	Total Additional Embankment Costs (dollars)	Additional Embankment Cost Per Acre Irrigated (dollars)
Calaveras						
	2	58	- 2/	5,800	19,333	333.33
	3	1/	1/	-	-	-
	8	-	56	5,600	41,949	749.09
	9	48	- 2/	4,800	29,271	609.81
	16	153	55	20,800	48,641	233.85
	18	67	0	6,700	28,271	421.96
Escondido						
	5	103	- 2/	10,300	39,225	380.83
	6	51	- 2/	5,100	38,686	758.55
	8	90	- 2/	9,000	36,891	409.90
	10	22	- 2/	2,200	16,132	733.27
	11	133	- 3/	13,300	50,396	378.92
Total		725	111	83,600	348,795	417.22

1/ Small acreage and oil field make this site undesirable for irrigation.

2/ Small acreage available will not justify a gravity system.

3/ Clearing costs excessive on land suitable for a gravity system.

NOTE: Only enough acreage to utilize the available water at 10 acres per square mile of drainage area was included in the investigation.

Water deficiencies as they affect crop production during the 12-year period studied were considered in determining the average annual net value of production. For example, with 15 acres irrigated per square mile of drainage area, the loss in crop production would be the equivalent of 1.3 years in 12; with 20 acres irrigated a loss of 2.4 years.

Average annual irrigation benefits were determined for 10 acres, 15 acres and 20 acres irrigated per square mile of drainage area. A summary of average annual net benefits is shown in table 63.

Annual Installation and Maintenance Costs

Installation costs were calculated for each irrigation site and were converted to an annual basis by the following methods:

1. Additional construction costs of embankment on the retarding structures were amortized over a 75-year period at a 4 percent interest rate.

2. The annual cost of the gravity distribution system was obtained by multiplying the distribution cost by an interest rate of 4 percent.

3. Embankment costs with a sprinkler system of irrigation remained the same as with a gravity system.

4. The annual cost of the sprinkler distribution system was amortized over a 10-year period at 4 percent interest.

The installation cost of either distribution system is estimated at $100 per acre irrigated. Annual maintenance cost of the gravity irrigation system is estimated to be 10 percent of the installation cost and for the sprinkler irrigation system 3 percent of the installation cost. A summary of estimated annual costs of the proposed irrigation systems with various acreages irrigated per square mile of drainage area is shown in table 64.

Comparison of Average Annual Benefit and Cost

A comparison of the average annual benefit with the average annual cost provides the economic evaluation of the irrigation systems.

An irrigation system with 15 acres irrigated per square mile of drainage area gives the most favorable benefit-cost ratio.

A summary and comparison of benefit-cost ratios with various acreages irrigated is shown in table 65.

CONCLUSIONS

1. Provision for irrigation storage would be economically feasible at a number of retarding structure sites.

Table 63. Summary of Average Annual Net Benefits, 1950 Prices, with Specified Acres Irrigated per Square Mile of Drainage Area

San Antonio River Watershed, Texas

Watershed	Site Number	10 Acres	15 Acres	20 Acres
		(dollars)	(dollars)	(dollars)
Calaveras Creek				
	2	2,351	3,153	3,570
	8	2,100	2,790	3,205
	9	1,945	2,609	2,954
	16	8,263	11,142	12,636
	18	2,715	3,624	4,123
Escondido Creek				
	5	4,773	6,437	7,294
	6	2,364	3,143	4,142
	8	4,171	5,599	6,373
	10	1,020	1,369	1,558
	11	6,164	8,305	9,419

Table 64. Estimated Annual Costs of Proposed Irrigation Systems, 1950 Prices with Specified Acres Irrigated per Square Miles of Drainage Area

San Antonio River Watershed, Texas

Watershed	Site No.	Annual Equivalent of Installation Cost			Annual Maintenance Cost After Installation			Total Average Annual Cost		
		10 Acres	15 Acres	20 Acres	10 Acres	15 Acres	20 Acres	10 Acres	15 Acres	20 Acres
		(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Calaveras Creek										
	2	1,595 1/	1,952 1/	2,310 1/	174	261	348	1,769	2,213	2,658
	8	2,065	2,177	2,555	560	840	896	2,625	3,017	3,451
	9	1,870	2,166	2,462	144	216	288	2,014	2,382	2,750
	16	3,660	5,973	7,279	1,695	936	1,248	5,355	6,909	8,527
	18	2,046	2,453	2,872	201	300	402	2,247	2,753	3,274
Escondido Creek										
	5	3,240 1/	3,875 1/	4,510 1/	309	464	618	3,549	4,339	5,128
	6	2,461	2,776	3,090	153	230	306	2,614	3,006	3,396
	8	2,989	3,544	4,085	270	405	540	3,259	3,949	4,625
	10	1,066	1,202	1,337	66	99	132	1,132	1,301	1,469
	11	3,868	4,688	5,508	399	599	798	4,267	5,287	6,306

1/ Includes loss in net income in structure sites.

Table 65. Summary and Comparison of Benefit-Cost Ratios 1/ of Proposed Irrigation Systems

San Antonio River Watershed, Texas

Watershed	Site No.	With 10 Acres Per Square Mile of Drainage Area	With 15 Acres Per Square Mile of Drainage Area	With 20 Acres Per Square Mile of Drainage Area
Calaveras Creek				
	2	1.31:1	1.42:1	1.34:1
	8	0.80:1	0.92:1	0.93:1
	9	0.97:1	1.09:1	1.07:1
	16	1.54:1	1.61:1	1.48:1
	18	1.21:1	1.32:1	1.26:1
Escondido Creek				
	5	1.34:1	1.48:1	1.42:1
	6	0.90:1	1.04:1	1.22:1
	8	1.28:1	1.42:1	1.38:1
	10	0.90:1	1.05:1	1.06:1
	11	1.44:1	1.57:1	1.49:1

1/ Based on 1950 Prices Received and Paid by Farmers.

2. Legal requirements for impounding surface water for irrigation purposes should be met before planning irrigation storage in any floodwater retarding structure. All normal flows have been appropriated for the months April through September, and only flood flows in excess of normal flows or flows which occur in other periods may be appropriated.

3. Storage capacity for at least 3 inches of runoff from the drainage area is necessary to insure economical construction and a practical irrigation system.

4. Storage is considered uneconomical on sites where embankment costs exceed $6,500 per square mile of contributing drainage area above the site. Lower embankment costs, combined with distribution costs, will produce a ratio of increased production or benefit to increased costs which will insure a profit from the installation.

5. The production of specialized crops, such as grass or legume seed, offers an opportunity to obtain greater returns from installation of an irrigation system. In cases of this type, increased costs of embankment for storage may be justified.

6. The experience and knowledge of the proposed irrigator, the market for products available, capital available and the economic situation should be considered during evaluation of the individual site and should weigh heavily in comparison with straight benefit-cost evaluation.